EVALUATION OF RESULTS OF SEMITUBULAR PLATING IN FRACTURES OF FOREARM BONES

THESIS
FOR
MASTER OF SURGERY
(ORTHOPAEDICS)

BUNDELKHAND UNIVERSITY
JHANSI (U.P.)

1991

SUNIL GUPTA

DEDICATED TO

(Late) PANDIT DEEN DAYAL UPADHYAYA

WHOSE IMMENSE DEDICATION

TOWARDS MANKIND

ALWAYS LITS THE PATH OF MY LIFE.

DEPARTMENT OF ORTHOPAEDIC SURGERY,
M.L.B. MEDICAL COLLEGE,
JHANSI (U.P.).

C E R T I F I C A T E

This is to certify that the work entitled "EVALUATION OF RESULTS OF SEMITUBULAR PLATING IN FRACTURE OF FOREARM BONES", which is being submitted as a thesis for M.S.(Orthopaedic Surgery) was carried out by Dr. SUNIL GUPTA, under my constant supervision and guidance.

The techniques embodied in this work were undertaken by the candidate himself. The results and observation were checked and verified by me periodically.

He has put in the necessary stay in the Department of Orthopaedics according to the University regulations.

Dated :

(P.K. DABRAL)
M.S.,
Professor and Head,
Department of Orthopaedic Surgery,
M.L.B. Medical College,
Jhansi (U.P.)

(GUIDE)

DEPARTMENT OF ORTHOPAEDIC SURGERY,
M.L.B. MEDICAL COLLEGE,
JHANSI (U.P.).

C E R T I F I C A T E

This is to certify that Dr. Sunil Gupta has worked on "EVALUATION OF RESULTS OF SEMITUBULAR PLATING IN FRACTURE OF FOREARM BONES", under my direct supervision and guidance.

His results and observation have been checked and verified by me from time to time.

Anurag

Dated : 3/12/90

(ANURAG)
M.S.,
Lecturer,
Department of Orthopaedic Surgery,
M.L.B. Medical College,
Jhansi (U.P.)

(CO-GUIDE)

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Sunil Gupta

Dated :

(SUNIL GUPTA)

C O N T E N T S

INTRODUCTION

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With the increase in civilization and industrialization of today's world, the dynamicity of life is also increasing and today's modern man has become much more prone to accidents than ever before. In this day to day mad rush of a twentieth century, accidents are bound to occur and with accidents fractures are inevitable. Fractures of the both bones of the forearm form a large number of all the long bones fractures presenting for treatment at an orthopaedic centre and certainly the most difficult to treat. The fractures of the forearm are common unsolved problem in the orthopaedic practice. Considerable ambiquity is still prevailing over the best line of management and regarding the various aspects of a particular form of treatment. The spectrum of treatment ranges from conservative methods of close reduction with plaster immobilization; to ASIF or AO techniques of rigid internal fixation along with compression.

Specific importance of forearm lies in fine skilled movements of the hand. The importance of these fine movements varies from person to person. For a labourer, the importance of these movements lies simply in performing his daily activities or lifting heavy objects

etc.; while on the other hand for a skilled worker, e.g. electronic engineer, surgeon, artist, or painter, these movements are of immense importance for his life. Any loss of these movements may even compromise his competence and professional excellence and render a great psychological trauma as well. In these persons, it is extremely important to give them fully functional hand. Because of these considerations, forearm fractures always need specific attention and accuracy as far as their treatment is concerned.

The forearm is an intricate, complex organ designed to meet the needs of hand. Before dealing with the treatment of forearm fractures, we should have a look on the complete surgical anatomy of the forearm. Forearm consists of two long bones radius and ulna which are approximately parallel, but they touch only at ends. They are bound together proximally by the capsule of the elbow joint and the annular ligament, and distally by the capsule of the wrist joint, the anterior and posterior radio-ulnar ligaments and the fibro-cartilaginous disk. The proximal and distal joints are very complex in both function and structure and are really many joints and not just two. They include the proximal and distal radio-ulnar joints and the ulnahumeral, radio-humeral and radio-corpal joints.

The articulation between the radius and ulna is in three parts; the proximal and distal radio-ulnar joint and the interosseus membrane which is the intermediate radioulnar joint. The behaviour of forearm fractures varies with the extent to which the radioulnar articulation is involved. The aim of treatment is return of normal function and this often, but not always coincides with re-establishment of normal anatomy.

Diaphyseal fractures of the radius and ulna because of the peculiar anatomical configuration, present some specific problems in addition to those common to all fractures of the shaft of long bones. In addition to regaining length, apposition and axial alignment, achieving normal rotational alignment is necessary if a good range of pronation and supination is to be restored.

The difficulty in reducing and maintaining the reduction of two parallel bones in the presence of the pronating and supinating muscles that have angulatory as well as rotational influences results in frequent malunion and non-union (Sisk, 1987).

Sage (1959) pointed out the complexity of the angles and curves in the raddi and the importance of maintaining them, to achieve good functional results. He found radius which is a relatively straight structure, demonstrated a radial bowing of approximately 9.3 degrees

and a dorsal bowing of approximately 6.4 degrees. If the forearm is placed in full supination, the radius demonstrates a lateral bow and the ulna a slight medial bow.

Between the shafts of the ulna and radius is the interosseous space. The fibers of the interosseous membrane run obliquely across the interosseous space from their distal insertion on the ulna to their proximal origin on the radius. The radius and ulna are joined by three muscles, the supinator, pronator teres and pronator quadratus, which takes origin on one bone and insert on the other. In addition to their named functions, when there is a fracture these muscles tend to approximate the radius and ulna and decrease the interosseous space.

The biceps and supinator muscles through their insertions exert rotational forces on fractures of the proximal third of radius. Distally the pronator teres inserting on the midshaft and pronator quadratus on the distal fourth of the radius exert rotational forces as well as angulatory forces. Fractures of the ulna tend to be affected primarily by angulatory forces as the proximal fragment usually displaces towards the radius. Fractures of the distal radius tend to angulate towards the ulna by the action of pronation quadratus and the pull of the long forearm muscles.

If satisfactory functional results are to be achieved in the treatment of fractures of the forearm,

it is not sufficient to maintain the length of each bone. Axial and rotational alignment must be achieved as well as the radial bow must be maintained. With the complexity of the bones and of the joints involved, and the many and varied deforming muscle forces, it is extremely difficult to obtain union with adequate restoration of the anatomy to ensure good functional results by closed treatment. Because of these factors, open reduction and internal fixation for displaced diaphyseal fractures in the adult is generally accepted as the best method of treatment even though close reduction may be achieved.

Although union may be achieved by closed methods, if angulatory and rotary malalignments are not completely corrected, some loss of function will occur and may make the overall result unsatisfactory. Both bones forearm fractures in adults represent difficult therapeutic problems whether they are treated conservatively or surgically (Sarmiento & Lallo, 1981).

In view of the controversies which are prevailing, regarding the best line of management of these fractures, this study was taken up to analyse and evaluate the results of semitubular plating (D.C.P.) in fractures of forearm bones.

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REVIEW OF LITERATURE

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In the age when Homo sapiens are going up and down the moon, living on artificial hearts and banking on nuclear weapons for their survival, the orthopaedic surgeon faces a rather basic but formidable question - Is it better to treat a fractured bone by rigidly immobilizing it, or by allowing it to move; and if so, to what extent ?

Since his origin, man is facing the problem of injuries and accidents, and is trying to cope up with it; so the history of surgery and particularly recognition of fractures with their treatment dates back, perhaps to the advent of man itself on this planet. Since no methods existed in those times to record events, there are no records of methods applied for fracture treatment during that period. Some glimpses however, are possible through the various scriptures which came into being subsequently. The evidences of Egyptologists prove beyond doubt that many thousand years ago, splints were used to fix broken bones in much the same manner as they are being used today.

In our country earliest references to the subject of healing of bones are found in Atherva-veda some 2000 years B.C. Later on Samhitas of Charaka and Sushruta,

originally written about 1000 years B.C. (Keswani, 1967), deal with the diagnosis and treatment of various types of fractures and dislocations.

Sushruta Samhita contains in it essence of all that was known with regard to Surgery and fundamental sciences closely related to this art. The orthopaedic treatment, which was based upon rich experience of the Surgery was rational and at times ingenious. Sushruta has described the fracture as 'Kanda Bhagna' and described 6 types of dislocations and 12 types of fractures, while dealing with diagnostic considerations (Nidan Sthana, second Conto of Sushruta Samhita quoted by Ninghal, 1977).

The fractures, after a correct diagnosis, were treated among other things, with traction by means of a pulley (Chakra).

Turkish Empire (1790) reported that the setting of bones was practised by enclosing the broken bones in case of plaster of paris.

Matthysen (1852), a Dutch man was the first to device Plaster of Paris bandages by rubbing the powder into coarse cotton material on a table. He popularized the use of plaster of paris bandages and recommended that the fractured limbs were to be immobilized with one joint distal till complete union occurred. Since then, a number of treatments of fractures, particularly for those of both bones forearm, have been deviced from time to time.

Till date there is unanimity of opinion regarding the difficulty in obtaining satisfactory results in displaced diaphyseal fractures of both bones in forearm but considerable ambiguity has been prevailing over the best line of management and regarding the various aspects of a particular form of treatment. Broadly, the methods have been divided into two categories - conservative and surgical.

The results of closed treatment in most series have proved unsatisfactory in a high percentage of cases. However, the report of Sarmiento & associates (1975) and more recently, the excellent book by Sarmiento & Lalta on the use of early functional bracing for forearm fractures are significant exceptions.

Many surgeons have preferred to treat these fractures conservatively. Evans (1945) dealt with the problem of rotational malalignment by recommending the use of 'bicipital tuberosity view' for closed reduction. Because the surgeons have no control over the proximal radial fragment with closed methods, he must bring the distal radial fragment into correct relationship with the proximal one. Ascertaining the rotation of the proximal fragment from the tuberosity view prior to reduction gives some idea of how much pronation or supination of the distal fragment is needed. The tuberosity view is made

with the X-ray tube tilted 20° towards the olecranon, with both humeral condyles and the subcutaneous border of the ulna flat on the cassette. According to Evans, pre-reduction bicipital tuberosity view gives an idea as to how much of the rotational deformity is to be corrected and a post-reduction view ascertains whether or not the rotational deformity has been corrected. This is done by comparing the post-reduction view with a diagram showing the prominence of the bicipital tuberosity in various degrees of pronation and supination or by comparing with a bicipital tuberosity view of the opposite elbow in a given degree of rotation.

Stuck & Thompson (1949) emphasized that most fractures of both bones of forearm can be treated satisfactorily by closed manipulative methods or by some form of traction. They further stated that there is a strong tendency towards non-union of fractures treated by open reduction and internal fixation because extensive tissue destruction required in such procedures interfers with the blood supply to the fracture site and this delays the healing of bone. Boyd, Lipinski & Wiley (1961) supported this view.

Key & Conwell (1951) found displaced forearm bone fractures amongst the most difficult ones to treat. They were in favour of atleast two closed manipulations

and surgical treatment to be used only as a last resort. Cave (1958) agreed with this view.

Watson Jones (1955) preferred to reserve surgical treatment only for those patients in whom it was not possible to get satisfactory closed reduction. According to him infection following open reduction and internal fixation may prove to be disastrous for the limb of the patient.

Bohler (1956) stated that breaking and bending of screws, plates and nails is often seen to result in failure of treatment by open reduction and internal fixation. He therefore preferred treatment by closed methods.

According to Charnley (1961), closed method of treatment can give excellent results but the element of luck is rather prominent.

Ralston (1967) advocates closed manipulation and Plaster of Paris fixation and states that most both bones fractures with complete displacement can be treated successfully by this method. According to him, most surgeons are not familiar with the correct technique of closed manipulation and plaster immobilisation, resulting in poor results by conservative methods.

Balton & Quinlan (1952) reported that average time of union of these fractures is more for surgically managed patients as compared to those treated conservatively.

Non-union rates reported by conservative treatment have been quite low with reports of 6% by Bohler (1956), 4.4% by Balton & Quinlan (1952) and 6.3% by Deburen (1962).

Sarmiento, Sinclair & Cooper (1975) tried functional bracing of forearm fractures. Sarmiento & Latta (1981) have reported good results with their method of conservative treatment by functional bracing. In support of their preferred method of treatment, they stated that, although displaced fractures of both bones of forearm are difficult to consistantly reduce and maintain reduced by non-surgical means; it has become clear that careful attention to details during the reduction and initial stabilization with above the elbow casts permits adequate reduction in many instances; thereby eliminating the need for surgical intervention which is associated with various complications such as infection, synostosis and non-union. Incidence of refracture following removal of plate although not high, can be significant. They further stated that anatomical reduction is not must for restoring good function. According to them, angulation of less than 10° of either or both bones of the forearm in any direction does not produce a major limitation of

pronation or supination. Also, the loss of radial bow does not necessarily produce major impairment of function. Cosmetic results which might be important to the patients are also better as compared to the operative treatment.

Anderson (1984), Sarmiento & associates are highly skilled in the use of functional bracing over a long period of years. This results have not been duplicated by others.

Anderson further stated, as a practical matter, I rarely attempt closed treatment for displaced fractures of both bones of the forearm in adults, unless some other condition of the patient prohibits surgery. The results are too uncertain and the period of immobilization too long.

On the other hand, the proponents of operative management have pointed out shortcomings of conservative management and the benefits of surgical treatment of displaced fractures of forearm bones.

Depalma (1970) stated "over the past decades there has been a considerable change in the philosophy of management of fractures of both bones of the forearm. In the hands of most orthopaedic surgeons, closed reduction has been unsatisfactory since this method of treatment represents a compromise in which malposition is accepted to ensure union (Sage, 1959).

According to Marek (1961), Evan's results obtained by conservative methods have never been duplicated in United States. Burwell & Charnley (1964) have noted that satisfactory initial reduction of displaced diaphyseal forearm fractures in adults may be obtained but the technique is not easy and two or more trial manipulations under anaesthesia and radiological control may be required. Should satisfactory reduction be obtained, redisplacement frequently occurs (Perkins, 1958; Holdswarth, 1962). Further manipulation is seldom successful (Bolton & Quinlan, 1952; Charnley, 1961). Even the undisplaced fractures particularly of lower shaft of radius and upper shaft of ulna show progressive angulation in plaster (Smith, 1959). The decision regarding timing of operation is difficult, particularly when displacement has progressed slowly over period of weeks (Watson Jones, 1955).

Muller et al (1979) have stated that anatomical reduction and restoration of double bow of radius is essential to achieve good range of pronation and supination. Depalma (1970) said that serious irreversible complications may occur as a result of prolonged period of immobilization in plaster such as flexion contractures of the elbow and shoulder joints, marked restriction of rotatory motion of the forearm, Sudeck's atrophy and formation of dense scar tissue around the malunited fragments which makes subsequent surgery very difficult.

Allgower & Spiegel (1979) have supported the views expressed previously by a number of surgeons (Hicks, 1961; Marek, 1961; Jinkins & Co-workers, 1960) and have favoured rigid internal fixation as the treatment of choice. According to them, rigid internal fixation decreases fracture disease, that is, muscle atrophy, joint stiffness and bony demineralization by early mobilisation without external support. This view was lent support by earlier reports of unsatisfactory functional results, following prolonged external immobilisation.

Knight & Purvis (1949) reported 74% unsatisfactory results and Bolton & Quinlan (1952) 41% unsatisfactory results with closed manipulation and plaster immobilization. Hughston found 92% with unsatisfactory results unless open reduction and rigid internal fixation were performed. In view of uncertain results and prolonged period of immobilisation by conservative methods, Anderson (1984) prefers open reduction and internal fixation for both bones forearm fractures. Sisk (1987) stated that due to complex angulatory as well as rotatory forces acting on both bones of forearm, conservative treatment results in frequent malunion and non-union. He adds in view of this, open reduction and internal fixation is deemed to be the best method of treatment of these fractures. Sargent and Teipner (1965) and later Grace & Eversmann Jr (1980) pointed out the economic advantage of no external immobilisation.

They stated that the patient benefits from comfort, and convenience of the absence of external immobilisation device following internal fixation and has an increased ability to perform every day tasks and to regain gainful employment.

Various modes of fixation have been used over the years to fix these fractures after open reduction. Open reduction without internal fixation has all the disadvantages of both open and closed treatment and has no place in the modern treatment of fractures of both bones of forearm in adults.

In the early 1900s, Lane of London, and Lambatte of Belgium, reported the use of plates on diaphyseal fractures. However, metal reaction led to frequent failures until modern metals for implantation were introduced in 1937 after the work of Venable & Stuck on electrolysis. Campbell used autogenous tibial grafts fixed to the radius and ulna with bone pegs or screws for acute fractures as well as non-unions. Some of these were successful, but unless external immobilization was very prolonged, the grafts often developed fatigue fractures before they were revascularized.

Intramedullary fixation was described by Nicolaysen (1897) and Delbet(1906). Earlier attempts were with small pins and not too successful, Sage (1959) stated,

commenting on poor results of Rush pins & Rush (1937) and Lambrinudi (1939) who used Kirschmer wires for intramedullary fixation of these fractures. After medullary nailing became popular for fractures of the femur in the late 1940's, various devices for medullary fixation of radius and ulna were used (Anderson, 1984).

Stuck & Thompson (1949) reported union in seventeen out of nineteen patients treated by them using Kirschner wires and Steinmann pins for intramedullary fixation after open reduction. Smith & Sage (1957) reported a series of 555 fractures collected from all over the country in which some form of medullary fixation had been carried out. The devices included - Rush pins, Kirschner wires, Steinmann pins, Lottes forearm nails and Kuntscher V. nails. The results were discouraging. Non-union resulted in over 20% of the fractures. This figure exclude Kirschner wires which failed in 38% of the cases. Even in the fractures which united mal-union and poor function were frequent. The radial bow was not maintained and the use of a round pin in a round medullary canal could not control rotation of the fragments. Coden reported a non-union rate of 16.6% in forearm fractures treated with Rush pins.

Sage (1959) published his study of the anatomy of the radius and introduced Sage triangular forearm medullary nails. The nails for the ulna are straight and

are inserted in a retrograde manner. The nail for the radius is bent to aid in maintaining radial bow. It is introduced from the radial styloid and driven proximally.

Sage reported good results with his nails. Non-union resulted in only 6.2% and delayed union in 4.9%. Other triangular or rectangular nails for the forearm bones were introduced by Ritchie & Street. These also grip the cortex well and control rotation but do not preserve the radial bow as well as the Sage nail. Sage nails are not recommended for fractures of the distal third of the radius after medullary canal has begun to enlarge. Also they should not be used if the medullary canal is less than 3 m.m. in diameter. But he mentioned that in the treatment of radial fractures, the technique is not simple, nor it is uniformly efficient. He also recommended routine autogenous iliac bone grafting.

Even after better metals became available, many of the early plates used for fractures of the radius and ulna were of poor design. Failures were frequent because adequate fixation was not achieved. For a time the use of plates and screws for the internal fixation of diaphyseal fractures in general fell into disfavour. Many surgeons treating fractures thought that fixation with plate and screws held the fracture distracted and caused delayed union and non-union (Anderson, 1984).

The first bone plate for fracture treatment was reported by Hansmann in 1886. This report was followed by Lambatte in 1909, Sherman in 1912 and by Lane in 1914. Each plate showed evidence of increased strength and tissue acceptance. The Sherman plate was significantly better than the weaker Lane plate because of its difference in contours and stronger steel (Vanadium). This plate, with round screw holes, was commonly used for many years, followed by a series of slotted plates.

The era of the slatted plate was introduced by Townsend & Gilfillan (1943), followed by Eggers (1946) and Callison in 1950. Townsend's technique was to apply the plate loosely, then, while an assistant impacted the fragments manually, the screws were tightened. Eggers proposed using the slotted plate (or contact splint, as he preferred to call it) with loose screws, and thereby relied on to the longitudinal muscle pull acting across fracture site to compress the fragments and hold them in close opposition, hoping that this process would encourage early union. After the first few days, fibrous tissue and callous grows into the slots so that sliding is no longer possible. Eggers plate was a much stronger plate than those used previously, and it provided better fixation. Jinkins and co-workers reported a series of 165 forearm fractures in 1960 in which 145 slotted plates and 20 medullary nails had been used. The overall non-union

rate was only 4.2%. They concluded that the results were best when a slotted plate was used for the ulna and either a slotted plate or a Rush pin for the radius. The Callison plate with shorter slots is a variation of the Egger's plate and was used in a similar manner.

Active compression created by a bone plate was introduced by Danis of Belgium in 1949. He used an axially-oriented screw within the plate to compress the fracture fragments. Danis called attention to the fact that diaphyseal fractures treated with these plates healed with very little peripheral callus, a phenomenon which he referred to as primary fracture healing. Venable (1951) and Bareau & Hermann (1952) described other compression plates with two parts in which a cylindrical bolt forced the fragments together. All three plates were awkward and ineffective in their compressive force. The introduction of Muller's plate in 1958 was a significant improvement over the Danis plate with its extraneous compressive device and improved screws provides better compression.

The Bagby plate was the first so-called self compression bone plate. The device was used at Mayo Clinic in 1956 to study compression as it relates to fracture healing (Bagby, 1957, 1977). Many variants of this self compressing plate are in common use today. The main efforts to improve these have concentrated on more rigid fixation properties, screws with better holding power,

screws with more precise fitting (Perren et al, 1969). These attempted improvement were designed to require less cast fixation, thereby permitting earlier movement of the adjacent joints, shorter healing time and better restoration of joint motion.

Compression for the purpose of healing of bone was first used by Key (1932) for arthrodesis of knee joint. He used percutaneous pin above and below the prepared surfaces of the knee joint with external turnbuckles. The tumberckle arrangement had the feature of dynamic compression force. When absorption and loosening of the fixation occurred, the tumbcerckles were lightened to maintain compression and close bony contact. Roger Anderson (1934) used a similar principle to treat fresh fractures of long bones.

The advantage of compression for fracture is to create close apposition of the bone fragments and to hold them rigidly together. This reduces the area of essential new bone formation, and protects the fragile, invasive vascularization necessary to precede bone callus.

In about 1958, Muller, Allgower and Willenegger developed what is now known as the ASIF (formerly A.O.) compression plates. The technique for using this plate and other recommended techniques of the Association for the study of internal fixation were published in 1965.

The plate is a modification of the plate of Danis but is much stronger, so more compression can be obtained (Anderson, 1984).

Lettin (1969) and Paavolaimen and Co-workers in 1978 have reported on the effects of rigid internal fixation of fractured bones. Lettin stated that callus formed in plated bones was firm and inelastic whereas in controls healed by plaster immobilisation, it was more pliable suggesting that latter was fibro-cartilagenous callus and the former woven bone. Paavolaimen & co-workers reported that bone subjected to rigid plate fixation maintained a nearly normal mineral and collagen content during the process of continuous remodelling by which the bone strives to adopt itself to the implant and to minimise the adverse effects of plate. Denham (1969) said that compression of bone ends in the fracture assisted union. Compression was effective simply because it closed an obvious gap, thus improving reduction, increasing fixation and lessening the need for new bone formation. Schenk & Willenegger (1967) showed in both dogs and humans that fracture could unite by primary bone healing if the fragments were rigidly fixed and there blood supply disturbed as little as possible so that under these conditions resorption and bone formation occurred simultaneously. Perren et al in 1969 showed that osteotomized rabbit tibial rigidly fixed with compression plates could heal by capillaries and haversian systems

extending directly across the osteotomy site producing cortex to cortex healing. Bassett & Ruedi in experiments in vitro showed the mesenchymal cells under compaction in the presence of a high oxygen tension might differentiate into osteoblasts, whereas under tension, distraction, or low oxygen concentration they might differentiate into cartilegenous or fibrous tissue cells.

Allgower & co-workers in 1969 reporting on dynamic compression plate said that less exposure was required for fixing these plates as no external tension device was required during fixation. Also these plates provided good stability and more homogenous appearance of healing fracture site. Naiman, Schein & Siffert (1970) reported 100% union rate in their study with the use of ASIF compression plates in 26 patients. Dadge & Cody (1972) reported 100% union rates in primary internal fixation using ASIF compression plates. With the development of superior forms of internal fixation, in routine cases involving intelligent and co-operative patients, post-operative plaster immobilisation can be dispensed with and early motion can be instituted (Guess, 1973). Teipner & Mast (1980) while comparing the use of double plating versus single compression plate in forearm fractures concluded that the new compression plates provided as good a fixation as double plates without the disadvantages associated with double plating such as

extensive exposure, more stress riser effect of implants and screw holes and increased operating time.

1960 onwards surgeons began using ASIF (formerly A.O.) compression equipment in clinical practice. Campbell Clinic and city of Memphis hospital from 1960-1970, 244 patients (216 with closed and 28 with open fracture) had 330 acute diaphyseal fractures of the radius and ulna which were treated by ASIF compression plates and followed from four months to nine years. Overall rate of union for the radius was 97.9% and for the ulna 96.3%. Excellent functional results were also achieved. With compression plate fixation early active motion is possible.

ASIF compression plates therefore, provided a successful method for obtaining union and restoring optimum function after acute diaphyseal fractures of forearm. Semitubular plates (D.C.P.) are types of compression plates. These plates are semi-tubular in cross section and have oval holes for screws. They are useful in subcutaneous locations. These plates are used in fractures of forearm, non-union of clavicle and to fracture of fibula.

Due to there semi-tubular shape they are better fixed according to contour of forearm bones to provide help in the mobility of forearm bones and do not interfere with the rotational movements. Very active mobilisation can be followed with the semi-tubular plates which will

lead to differences in long term results. Early active motion helps to prevent muscle atrophy and joint stiffness. Thus, dynamic compression plates are best method at present for the fixation of fractures of forearm.

Besides the differences on the type of implants to be used, views have differed regarding other aspects of surgical treatment too. Smith (1959) in his studies found that patients in whom the internal fixation had been done in less than one week after injury had significantly higher non-union rate of 22% than those in whom it had been delayed for three weeks following injury. Lam (1964) supports Smith's view. Early operation according to them, further compromises the already severely affected blood supply to soft tissue structures surrounding these fractures. Rosacker and Kopta (1981) found delayed surgery to be an important factor in obtaining primary union. Hick (1964) contradicted Smith's view and said that Smith's view regarding delayed plating seems to be valid when applied to the results of ordinary plating but it becomes less important in case of rigid plating. Dodge and Cady (1972), Anderson (1984) and Sisk (1987) favoured early internal fixation for forearm bone fractures.

Controversy also exists regarding the extra-periosteal or sub-periosteal fixation of plates. Some surgeons (Hicks, 1961; Charnley, 1964) preferred to apply

the plates extra-periosteally. Anderson (1984) also stated that periosteum should not be stripped to expose the bone. Less damage is done if the muscle is dissected free from the periosteum and the plate is placed on top of the periosteum. Lesker and Whiteside (1978) based on their own work and experiments of Zucman (1960) are in favour of extraperiosteal fixation of plates. Sisk (1987) advocates minimal stripping of the periosteum from the bone without dissecting the muscle away from the periosteum. He added that placing the plate beneath the periosteum on the bone should produce less injury to the local blood supply.

Views have also differed over the role of external immobilisation following open reduction and internal fixation. Watson-Jones (1955) favoured use of external plaster immobilisation following internal fixation till fracture united. DeBuren (1962) stated that plating without subsequent immobilisation in plaster is a method to be abandoned. Cowie (1957) did not use post-operative plaster and reported good results. Cruess (1973), Anderson (1984) and Sisk (1987) preferred to assess each patient individually based upon the patients intelligence, co-operativeness, type of fracture and adequacy of fixation. In general, if fixation is good and patient is co-operative and intelligent he is not given post-operative immobilisation but was advised to do only light work without any load

bearing till the fracture unites. Otherwise, the patient is made to exercise gently (under supervision) the joints and muscles of the operated limb, till skin sutures are removed. After that, he is given plaster immobilisation till the fracture shows signs of union.

Hadden, Reschauer and Seggl (1984) have pointed out that although compression plating leads to excellent results in a majority of patients, it is also associated with serious complications in a minority. Surgeons utilizing the method must be able and willing to treat these complications. Anderson and co-workers (1975) reported that most of the failures were due to errors in technique or infection. Anderson (1984) stated that before compression plating is undertaken, the surgeon must be thoroughly familiar with the technique. A complete set of equipment must be available and rigid aseptic technique must be enforced on the operating room. Hidaka and Gustilo (1984) reported seven refractures of 32 forearm fractures in 23 patients following plate removal. Sisk (1987) stated that refractures are less if a rigid compression plate is removed after one year and the longer the delay, the less is the chance of refracture. He did not recommend routine removal of forearm plates in the average patient.

Sage (1959) stated that achieving union is of paramount importance. Over the years, however, the emphasis

has shifted to achieving union with good function. In words of Grace and Eversmann Jr. (1980) "success in the treatment of fractures of one or both bones of the forearm means that union of fracture is achieved with minimum restriction of motion in forearm, wrist and elbow and with restoration of good muscle strength without pain. The merits of any treatment regimen should be judged on these criteria because failure to achieve any one of them will compromise the functional results.

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MATERIAL AND METHODS

MATERIAL AND METHODS

The present clinical study is based on twenty two patients with closed, displaced diaphyseal fractures of radius and/or ulna, treated in the Department of Orthopaedic Surgery, M.L.B. Medical College, Jhansi, from 15th September 1989 to 14th September 1990.

On admission detailed history regarding mode, type and duration of injury was taken. Enquiry regarding massage and manipulation and thorough local and general examination of patient was made. Clinical assessment of the fractured limb was made and the presence of any neuro-vascular complication was noted. Routine antero-posterior and lateral radiographic views of the injured limb were taken and assessed for the displacements and angulations. Detail history and clinical examination were recorded in the working proforma as follows :

Working Proforma

Case No. : MRD No. :

Name of patient :

Father's/Husband's name :

Age/Sex :

Address :

Ward/Bed No. :

Occupation :

Date of admission :

Date of injury :

Date of discharge :

Mode of injury :

History of present illness :

Time between injury and Ist immobilization :

Any previous treatment taken:

Any associated injury :

Examination :

General condition : Blood Pressure :

Consciousness : Pallor :

Pulse rate : Icterus :

Respiratory rate : Hydration :

Systemic Examination -

Cardio-vascular system :

Central nervous system :

Respiratory system :

Abdomen :

Local Examination -

Side : Right / Left / Both

Nature : Compound / Simple.

Site : Proximal third / Middle third/ Distal third.

Bones involved : Radius / Ulna / Both bones.

Regional arterial pulsations (Radiol.) :

Condition of regional nerves :

Any associated local injury :

Investigations -

Blood : Hb% TLC, DLC, ESR

Blood sugar : Random

Blood urea :

Urine : Albumin, Sugar, Microscopic examination

Radiological Examination -

Treatment :

Procedure done:

Date of operation :

Post-op. X-ray film - State of fixation :

Post-op. complications :

Infection :

Nerve palsy :

Any other :

Date of removal of external support :

Follow-up : 4 weekly interval.

Condition of stitch line

Range of movement -

Flexion :
Extension :
Pronation :
Supination :

State of union :

Strength :

Wasting :

Complications :

Functional Result -

Following criteria were used for plating of both bone forearm.

- Adult with displaced fractures of the shaft of the radius or ulna.
- Fractures associated with dislocation, Galeazzi's fracture dislocation and Monteggia fracture dislocations.
- All grossly comminuted fractures were excluded.
- In all the open fractures internal fixation was delayed for one to three weeks, to be certain that infection was not present.
- Old fractures with mal-union, non-union or delayed union.
- Primary autogenous iliac bone grafts were used for fractures in which more than one third of the circumference of the shaft was comminuted and for old fractures (i.e. malunited, delayed union and non-united cases).

After admission on the same day, closed reduction under anaesthesia was attempted and the limb was immobilised in the above the elbow plaster of paris cast. Limb was kept elevated. The patient was encouraged to do active finger movements on recovery from anaesthesia and was observed overnight for circulatory embarassment. Check antero-posterior and lateral radiographs were taken on the following day. If the reduction was satisfactory, the conservative management was continued. Periodical radiographs were taken in the Out Patient Department. During this period, patient was taught active shoulder and hand exercises. Once the fracture had united clinically and radiologically, plaster of paris immobilisation was discarded and active exercises of the immobilised joints were begun. The patients in whom the closed reduction was unsatisfactory or the ones in whom it was lost subsequently, were taken up for surgery. Criteria for satisfactory reduction were none or minimal rotation of the distal fragment and no over-riding or angulation of the fractures fragments.

On deciding upon open reduction and internal fixation, the patients were taken up for surgery as soon as possible. The implants to be used for surgery were selected pre-operatively. Criteria for implant selection included, location of fracture site, fragment geometry, presence of comminution and size of the bone in question

as evident on the pre-operative radiographs. Indian semi-tubular plates (D.C.P. and Small fragment set D.C.P.) for use with 4.5 m.m. and 3.5 m.m. cortical screws were utilized in the present study.

Surgery was performed under strict aseptic conditions. Fractures of the proximal and middle thirds of the radius were exposed by Thompson's or dorsal approach in the plane between extensor digitorum communis and extensor carpi radialis brevis muscle. The fractures of lower third of shaft of radius were exposed by Henery's or anterior approach through the interval between brachioradialis and flexor carpi radialis muscle. Fractures of the shaft of the ulna were exposed by Boyd's approach. Care being taken to strip the periosteum sparingly, the fractures were then reduced as anatomically as possible. The plates were applied subperiosteally on the posterior surface of the ulna and on the postero-lateral surface of radius, using the standard ASIF technique and instrumentation. Supplementary autogenous cancellous bone grafting was done in patients where significant comminution or for delayed union and non-union. Suction drains were not used and wound sutured. The wounds were cleaned and dressed and an above the elbow posterior plaster of paris slab was given with the elbow flexed to 90° and forearm in mid-prone position.

Post-operatively, the operated limb was kept elevated. On recovery from anaesthesia, the patient was encouraged to do active finger movements. Active shoulder movements were begun, usually 24 - 48 hours after surgery. Proper antibiotic cover was provided. Antero-posterior and lateral radiographic views of the operated limb were taken post-operatively to see the alignment of fragments and the position of implants.

The duration of the external plaster immobilisation depended upon the co-operativeness of the patient, adequacy of fixation, amount of comminution and whether or not bone grafting was done. It was usually continued 3 weeks after suture removal in co-operative patients in whom rigid fixation had been secured. If bone grafting had been done, it was continued 4 - 6 weeks. The patient in whom the fracture was significantly comminuted or rigid fixation was not achieved, the external immobilisation was prolonged till the fracture showed signs of union.

All the operated patients were taught and encouraged to do exercises of the shoulder and hand of the operated limb till the external plaster immobilisation was present. Once the external immobilisation was discarded, gentle active exercises of all the joints of the operated limb were begun. The patients were advised to restrict the use of operated limb for performing light activities only and not to bear load or do any strenuous work with the operated limb, till the fracture had united.

Patients were followed up at intervals of four to six weeks. Follow-up included check antero-posterior and lateral radiographs of the operated limb and movements in the joints of the operated limb as compared to the joints of the normal opposite limb of the patient. Any complication which occurred was noted and treated accordingly. Forearm and arm atrophy in the operated limb were assessed as compared to the normal opposite limb. The time interval between injury and return to work was also noted.

Criteria of Muller et al (1950) for the union were followed i.e. obligeration of fracture line and bridging of trabeculas.

The criteria for functional assessment in the injured limb were as shown in the table.

Table I

Criteria for functional assessment in the injured limb as compared to the normal opposite limb of the patient.

	Union	Flexion/ Extension at elbow or joint.	Supination and pronation
Excellent	Present	Less than 10° loss	Less than 20% loss
Satisfactory	Present	Less than 20° loss	Less than 50% loss
Unsatisfactory	Present	More than 30° loss	More than 50% loss
Failure	- Non-union with or without loss of motion.		

Criteria used by Anderson & Co-workers (1975) in their series at Campbell Clinic.

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AIMS AND OBJECTIVES

1. To evaluate the functional results of semitubular (DCP) plating in fractures of forearm bones, with reference to the normal limb of the patient.

2. To analyse the rationale of external immobilisation after rigid fixation of the fractured bones.

3. To assess the average time taken for union in fractures after open reduction and internal fixation.

4. To study and assess the complications encountered during the treatment.

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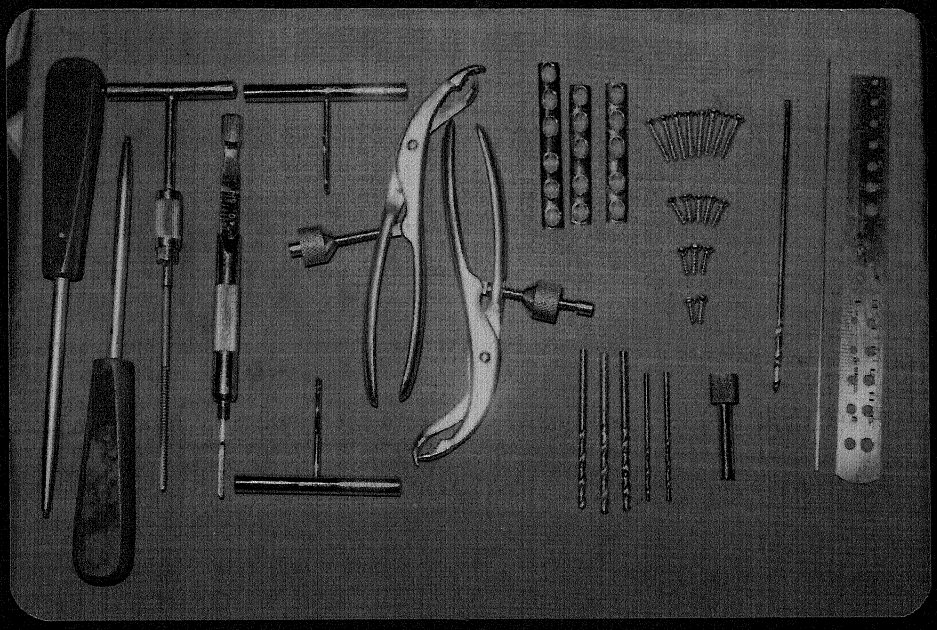
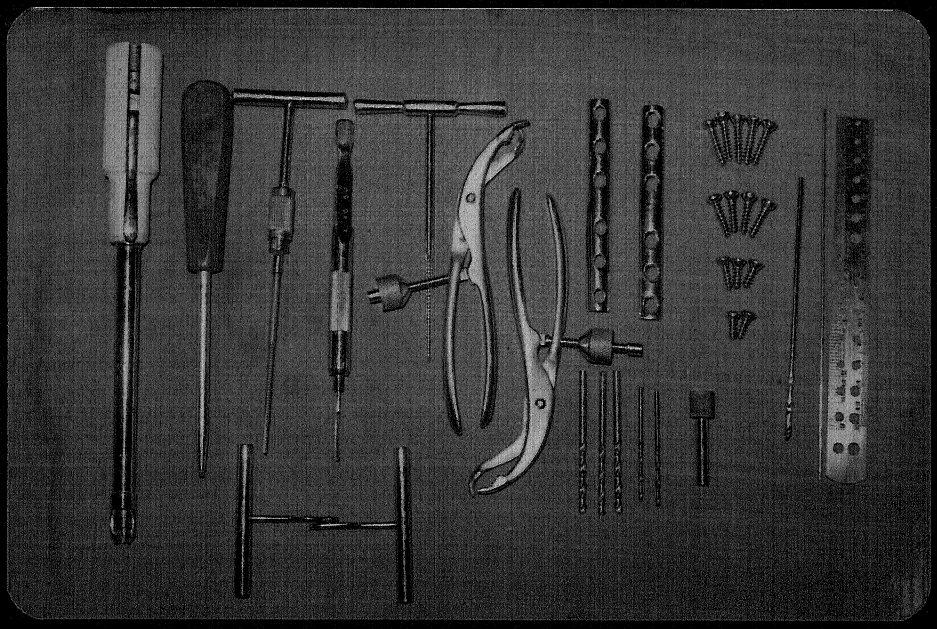
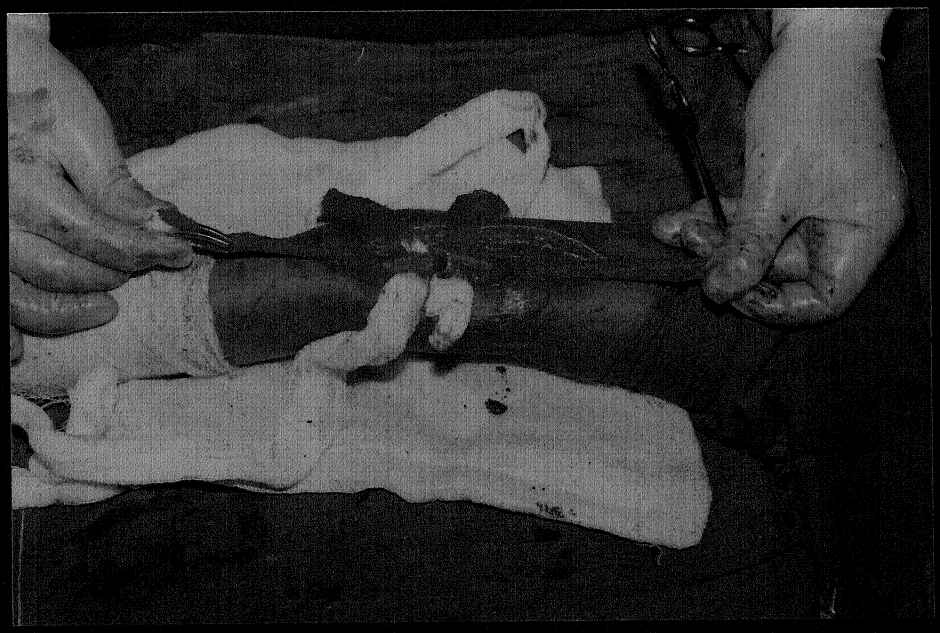


Complete set of Instruments
with Semitubular plates
(S.F.S. D.C.P.).



Complete set of Instruments
with Semitubular plates (D.C.P.)

Part painted and draped.



Fracture ends of radius exposed.

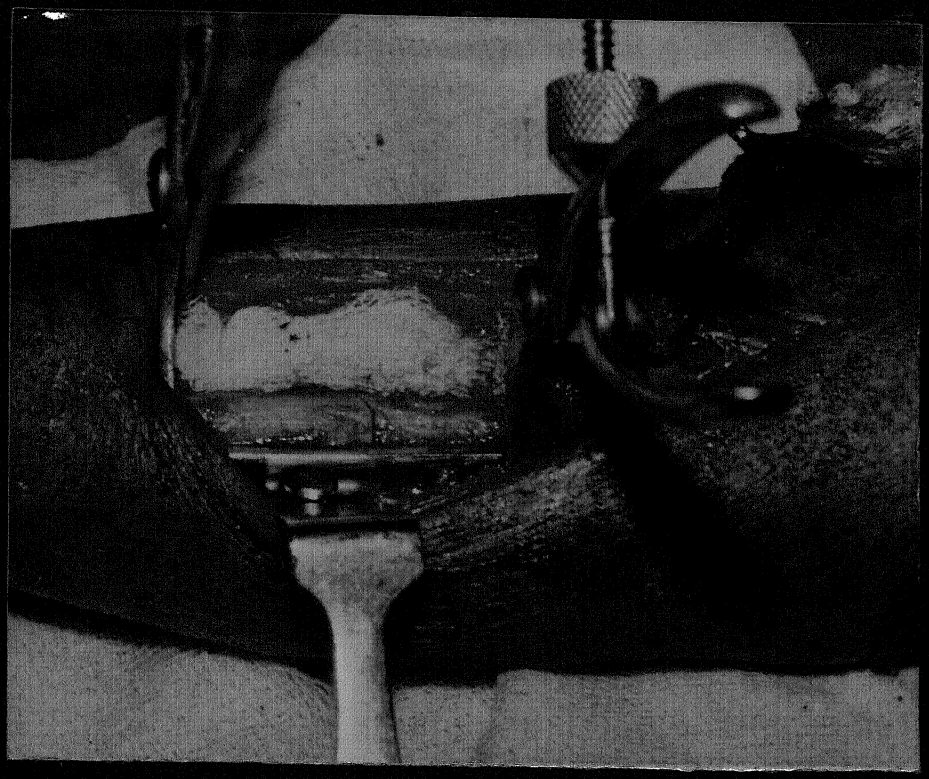
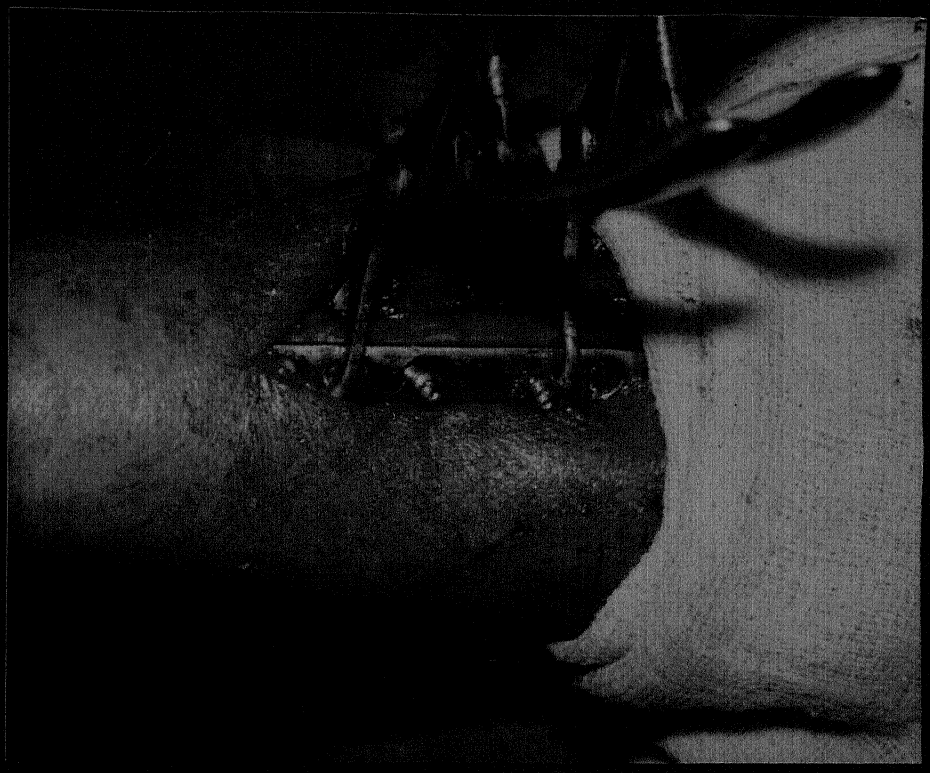
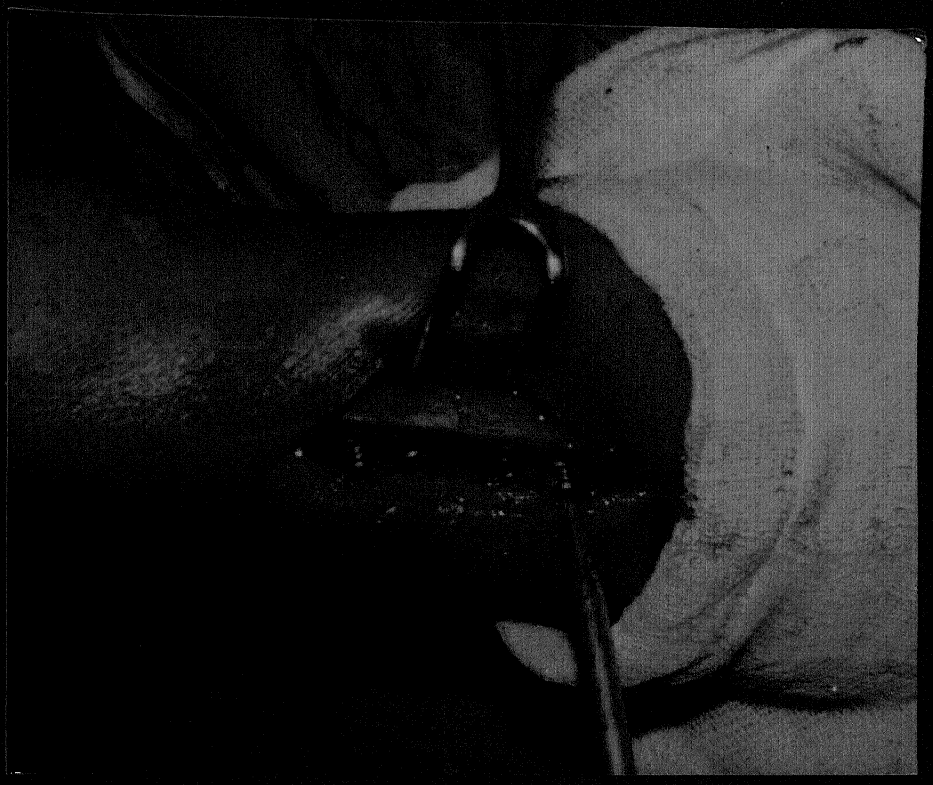


Plate applied after open reduction.



First two screws tightened.



First four screws tightened.

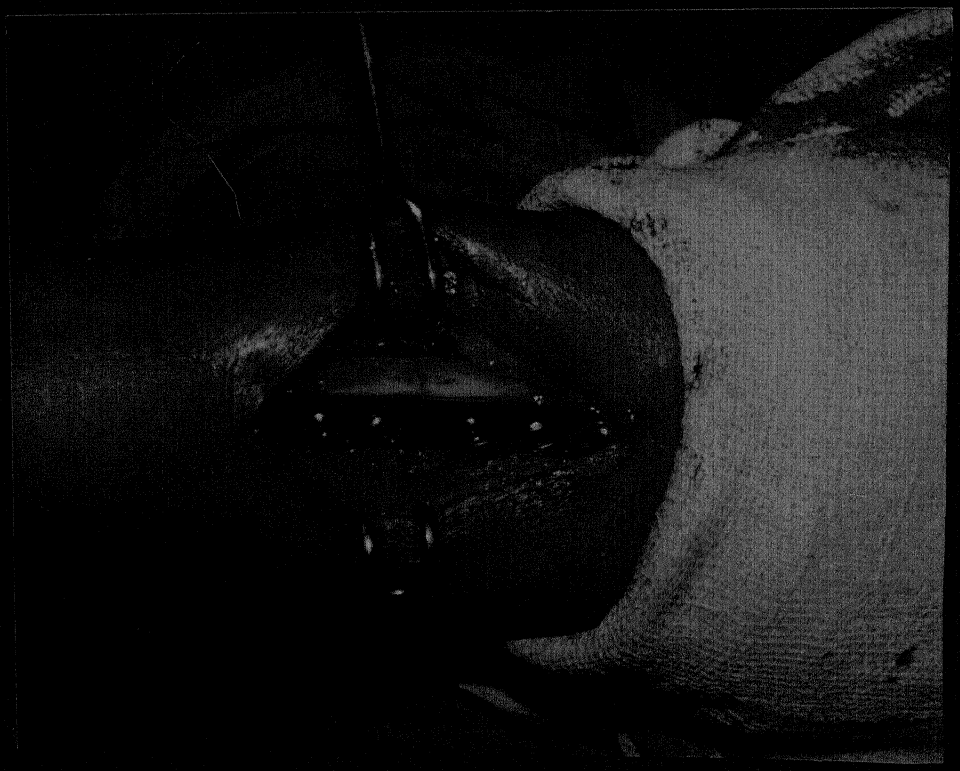


Plate after fixation of
all six screws.

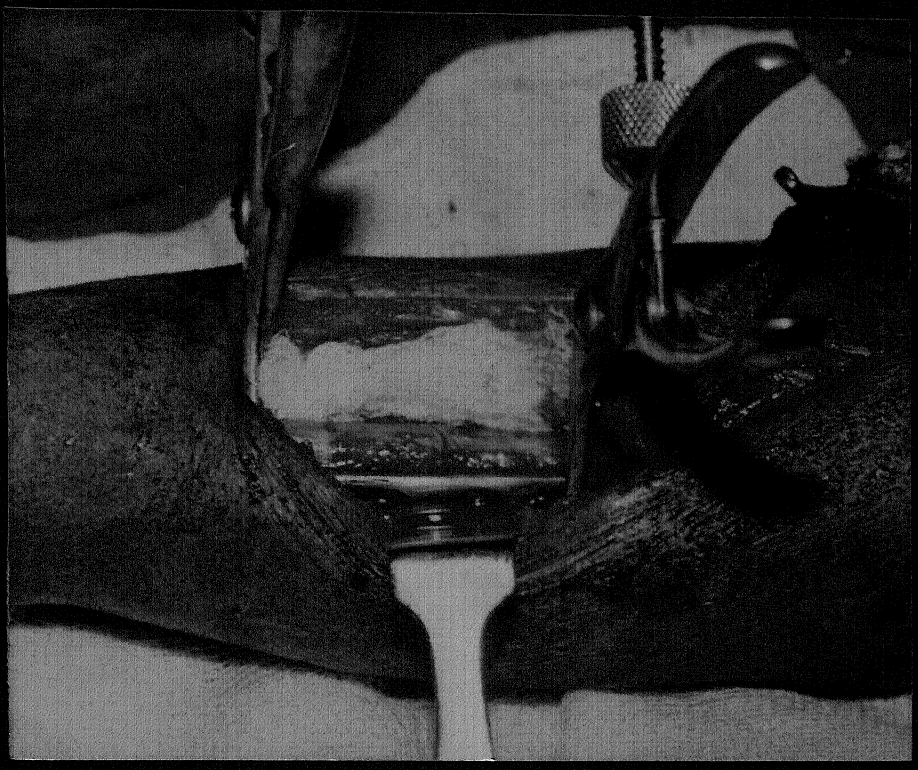
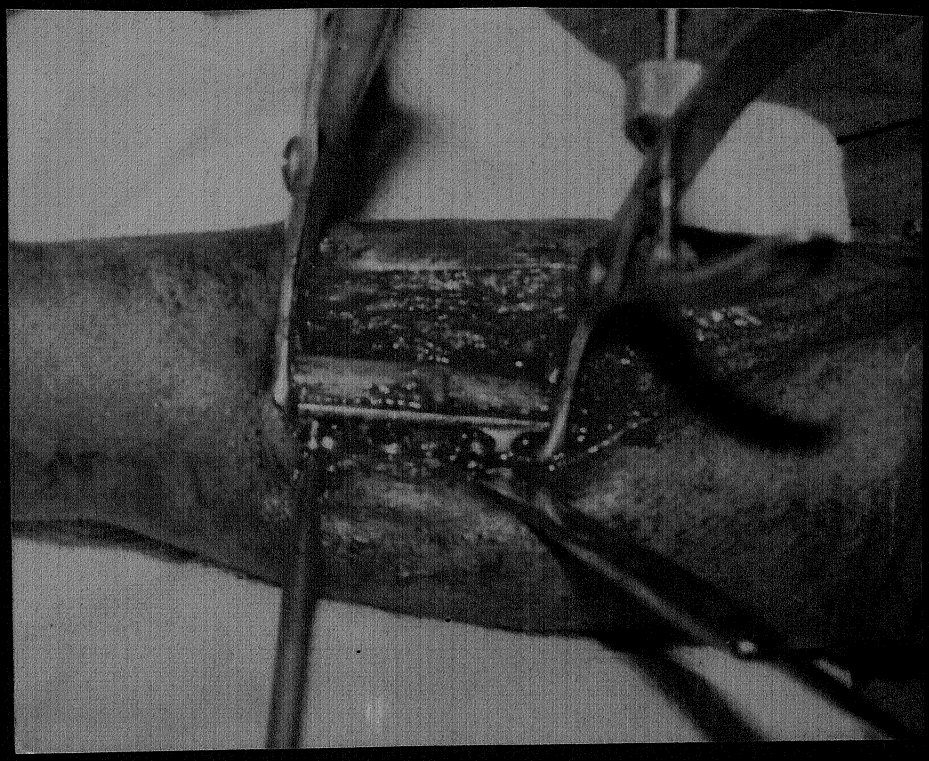
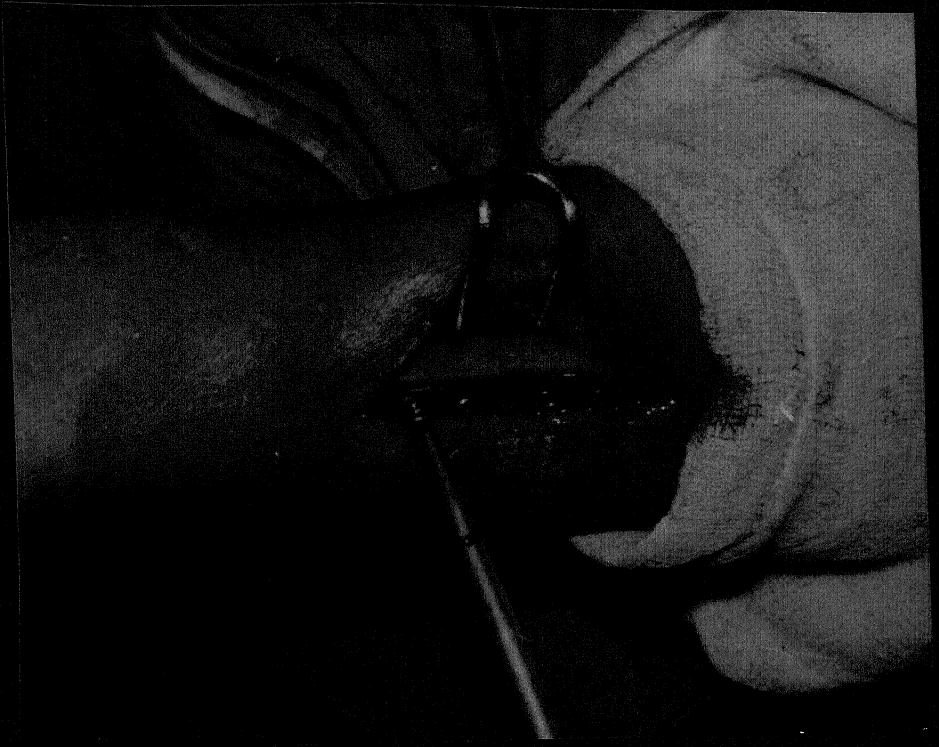


Plate applied after open reduction of Ulna.



First two screws tightened.



First four screws tightened.

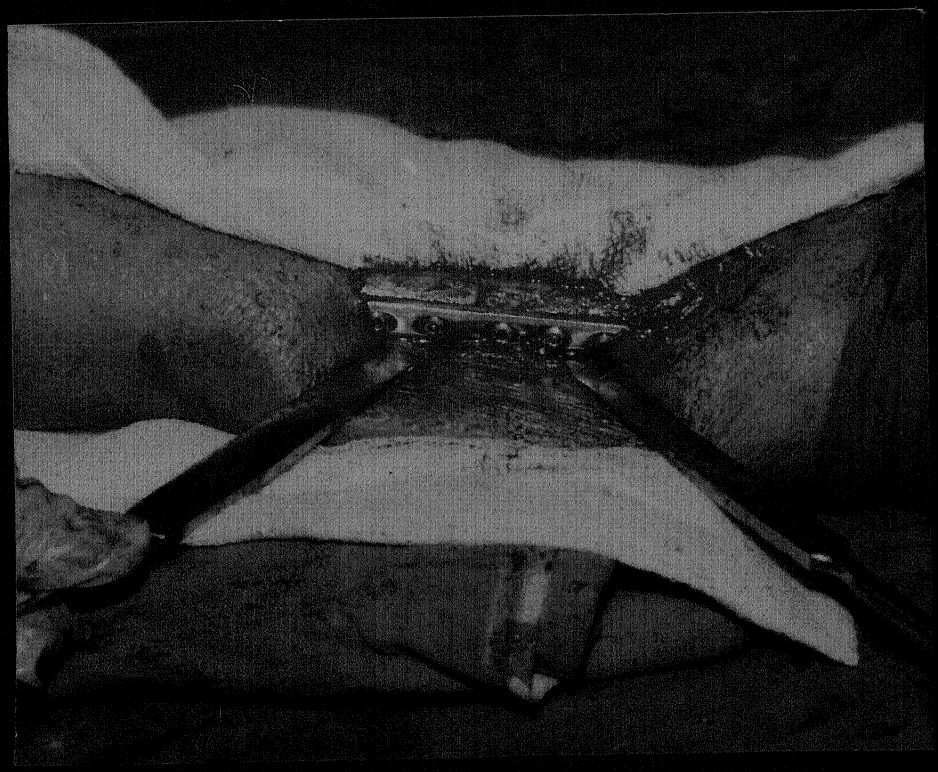


Plate after fixation of all screws.

After subcutaneous stitches.

Skin stitches given.

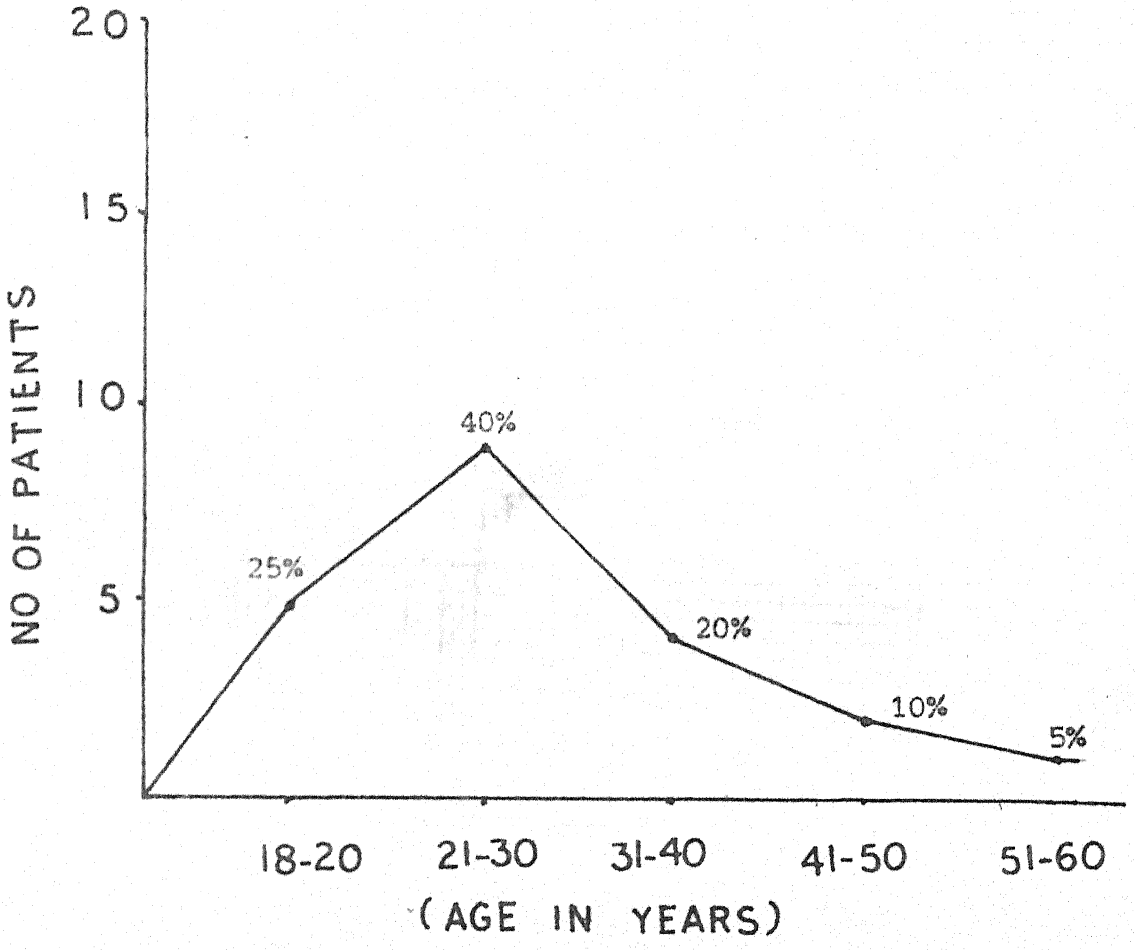
OBSERVATIONS

OBSERVATIONS

The present study included twenty patients with 34 acute diaphyseal fractures of the radius and ulna which were treated with semitubular compression plates (D.C.P.). In four patients compression plating was done in ulna and nailing was done in radius due to higher fracture site of radius. Fourteen patients had fractures of both bones of forearm; three single fracture of radius of which two were Galeazzi fracture dislocation and one fracture of middle of shaft of radius; three single fracture of ulna of which two were monteggia fracture dislocation and one fracture of lower end of ulna. In all seventeen fracture of ulna and twelve fracture of radius were treated by compression plating. One patient had 3½ month old malunited monteggia fracture dislocation and one patient had 9 month old non-union of fracture of both bones of forearm. In both of them iliac bone grafting was done. All the patients were male, in the age group from 18 to 60 years (Table II).

TABLE II

Showing distribution of cases according to age and sex.

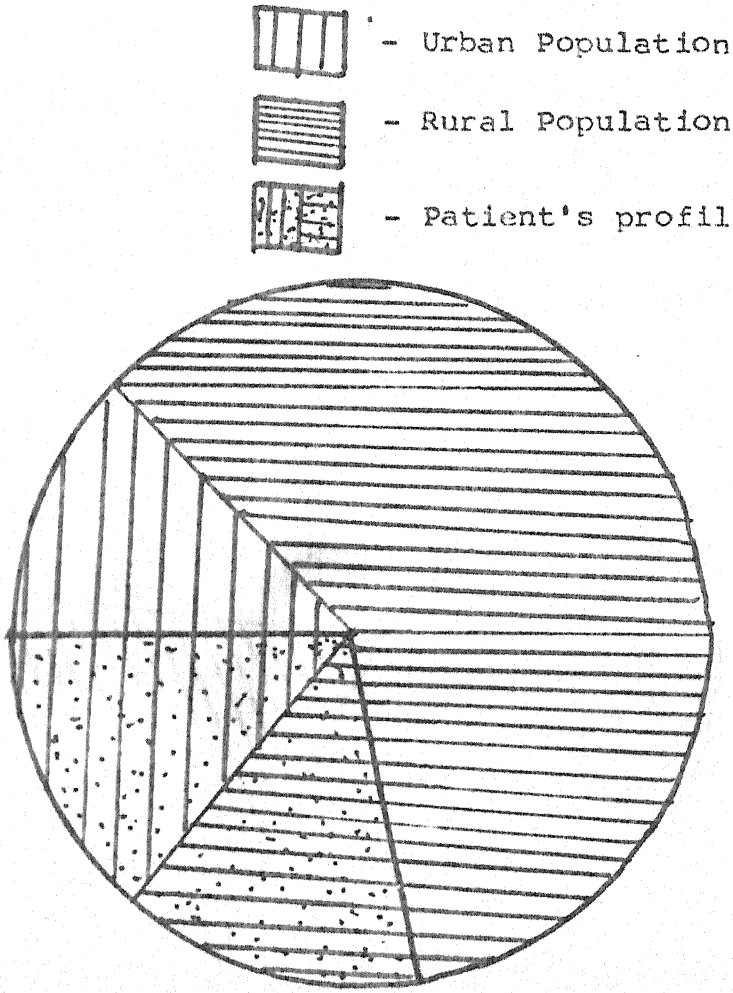


Mean age : 28.25 years.

All the patients were male showing vulnerability of the male patient, to this injury as they are having more outdoor activities.

TABLE III

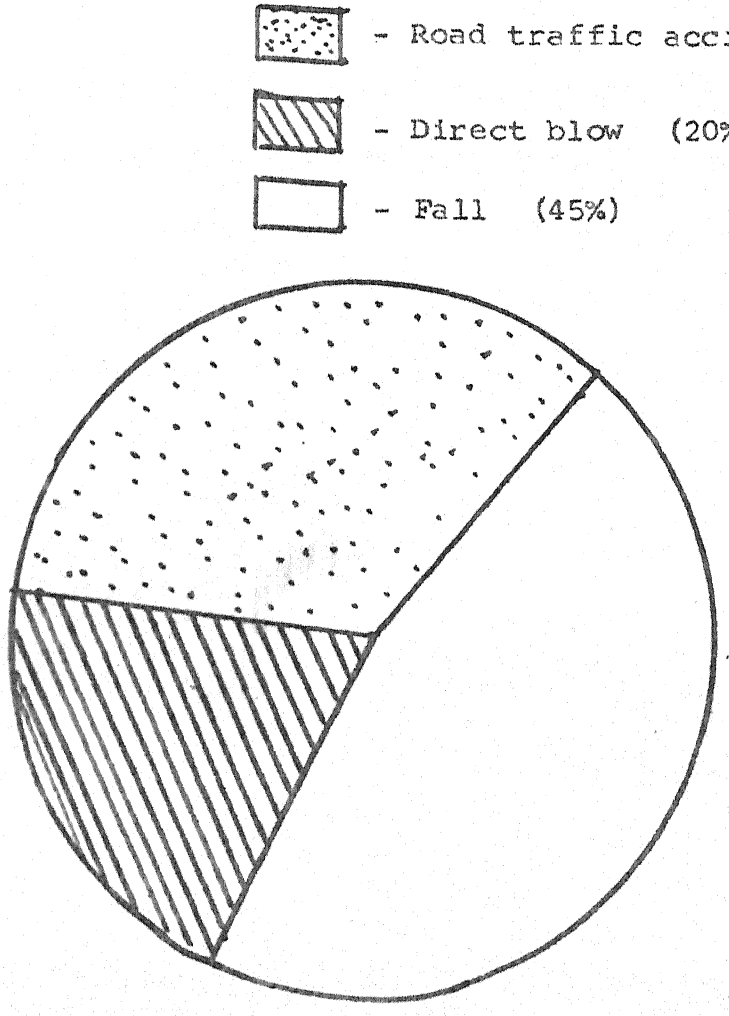
Showing distribution of cases by domicile.



According to demographic profile of Indian population, seventy percent is rural and thirty percent is urban. Fifty percent of cases from urban population again represent the vulnerability of urban people for this type of injury due to their more mechanical life pattern.

TABLE IV

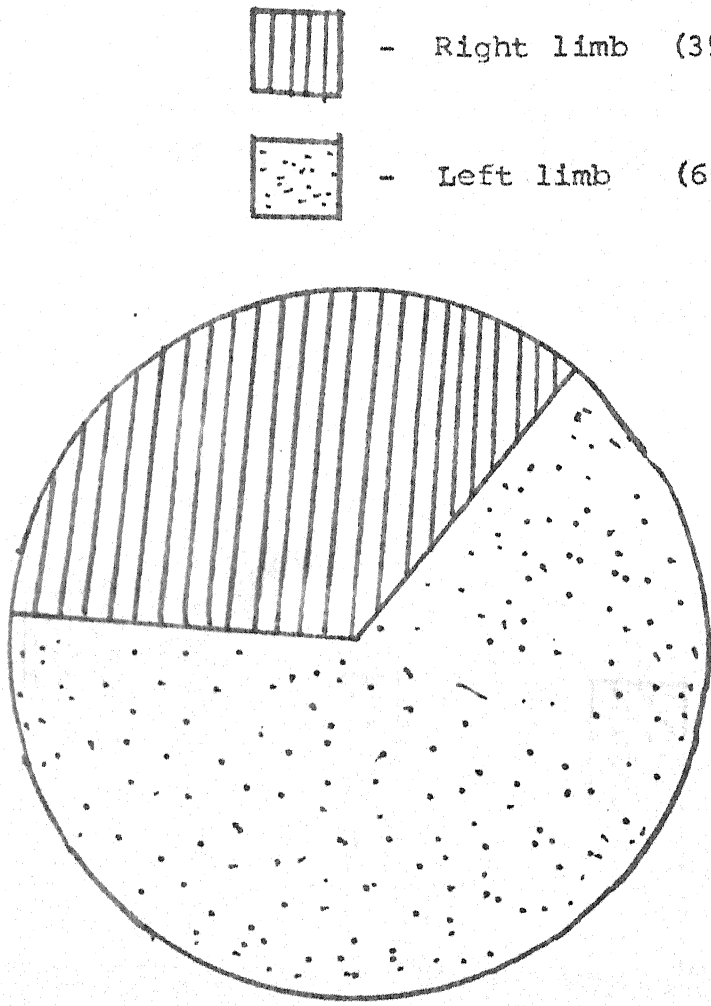
Showing distribution of cases according to mode of injury.



Thirty five percent of cases were the result of high energy trauma due to road traffic accidents. Forty five percent of cases were due to fall while moving or working or playing or doing exercises. Four cases (20%) were caused by direct blow of hard object in an altercation.

TABLE V

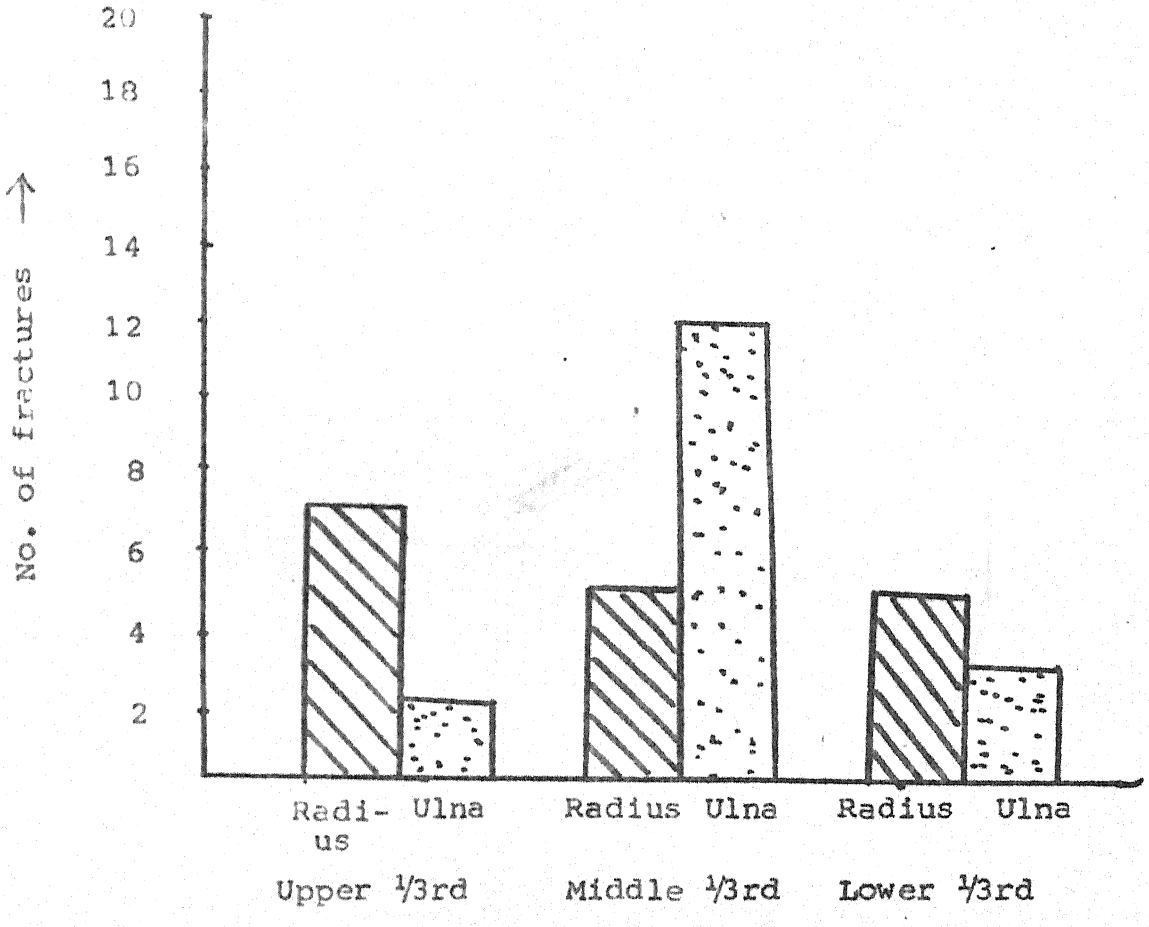
Distribution of cases according to limb involved.



Incidence of injury was higher on left side (65%) or on non-dominant side.

TABLE VI

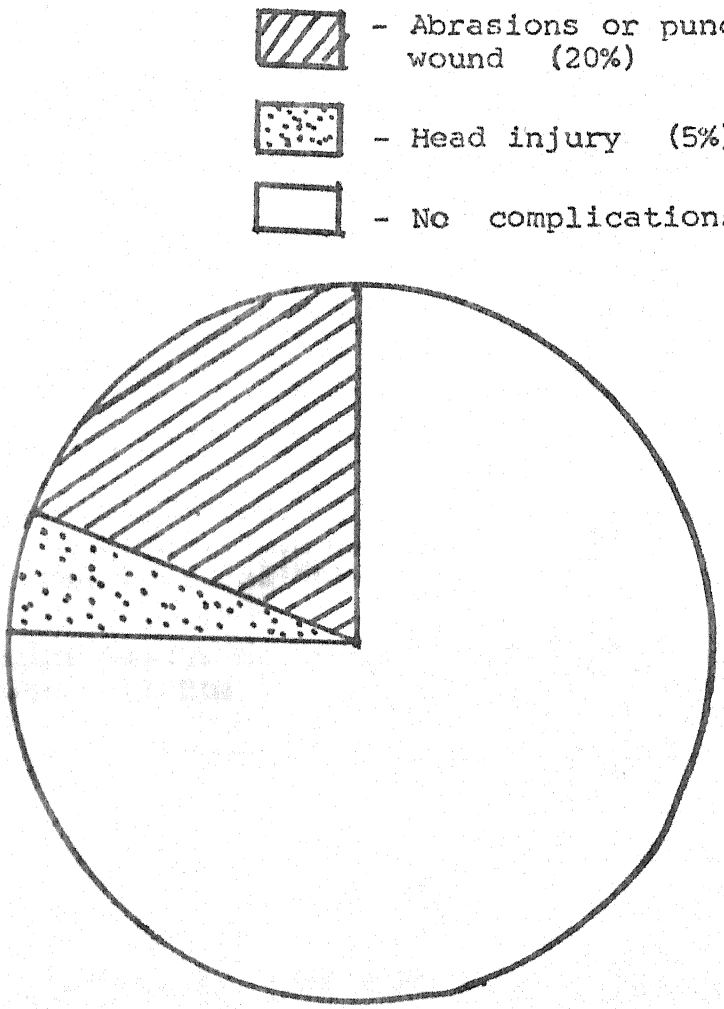
Distribution of cases according to level of fracture.



Maximum incidence of fracture was in upper 1/3rd in case of radius and middle 1/3rd in cases of ulna.

TABLE VII

Associated injuries.



Seventy five percent patients were without any complications.

TABLE VIII

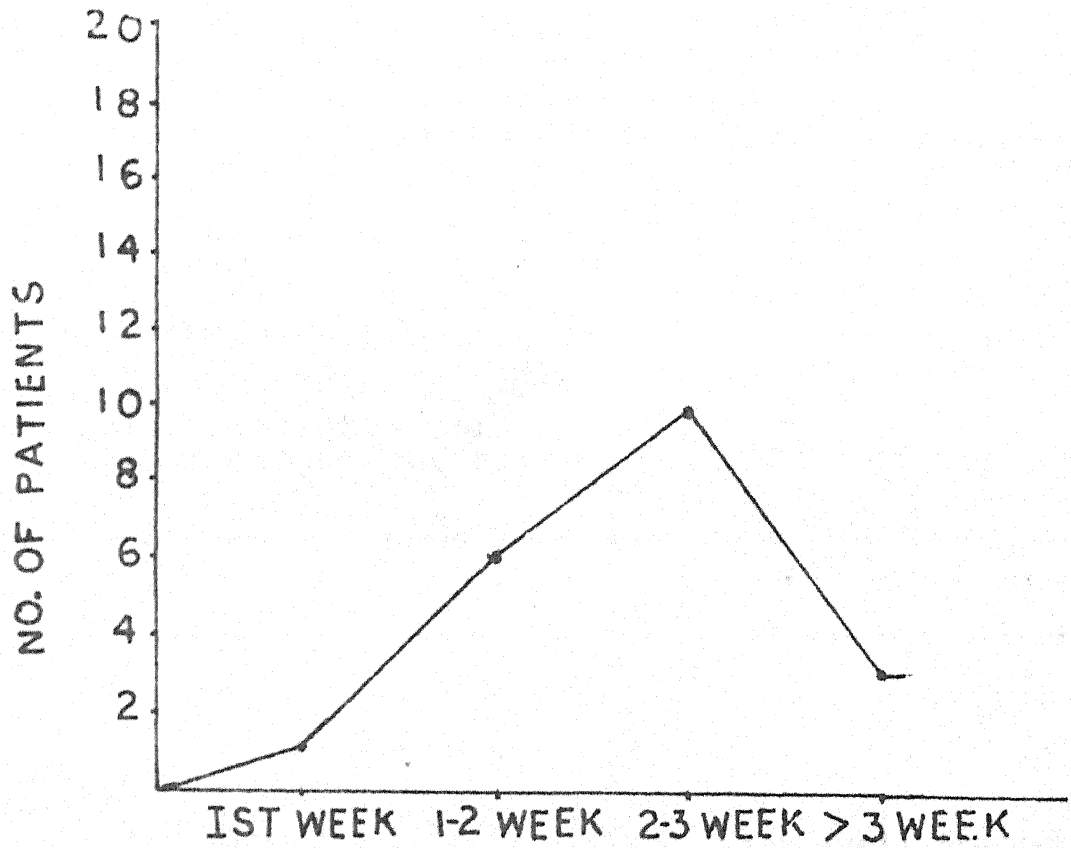
Distribution of cases according to different modes / implants used for treatment.

Treatment	No.of cases	No. of plates
Open reduction and internal fixation using :		
1. Semi-tubular dynamic compression plates with 4.5 mm. cortical screws.	7	10
2. Semitubular small fragment set dynamic compression plates with 3.5 mm. cortical screws.	8	14
3. Semitubular plates for ulna and square nail for radius.	5	5
Total	20	29

In four cases fracture site of radius was higher and in one case fracture of radius was severely comminuted, so in these five cases square nail was introduced in radius alongwith compression plating for ulna; compromising rigidity of fixation in case of radius fractures.

TABLE IX

Time interval between injury and open reduction and internal fixation.



Most of the cases were operated within three weeks of injury. Cases operated late included mal-union and non-union.

TABLE X

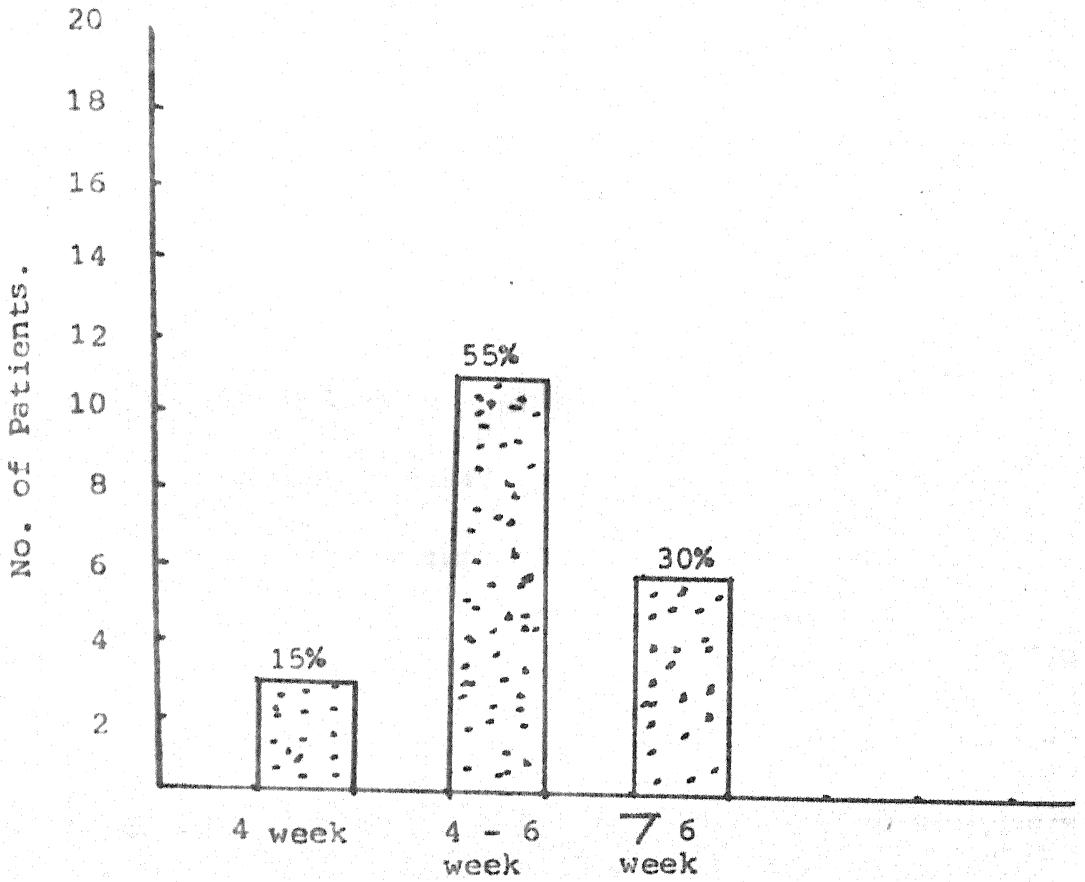
Adequacy of fixation using different types of implants.

Type of implant	Rigid fixation	Inadequate fixation
1. Semitubular dynamic compression plates with 4.5 m.m. cortical screws.	6	1
2. Semi-tubular small fragment set dynamic compression plates with 3.5 m.m. cortical screws.	8	0
3. Semitubular plate for ulna and square nail for radius.	0	5
Total	14	6

Rigid fixation was achieved with small fragment set dynamic compression plates and compromised fixation was obtained when square nail was used for radius along with compression plating of ulna.

TABLE XI

Duration of post-operative Plaster of Paris immobilisation.



Duration of Plaster of Paris immobilisation.

Most of the patients were given plaster immobilisation for 4 - 6 weeks. Patients who were immobilised for more than 6 weeks mostly include those cases with compromised fixation due to square nailing of one bone.

TABLE XII

Post-operative complications.

No.	Complications	No.of cases	Percentage
1.	Superficial infection	3	15.0
2.	Deep infection	0	-
3.	Implant failure	1	5.0
4.	Non-union	1	5.0
5.	Neurovascular :		
	- Tourniquet Palsy	2	10.0
	- Posterior interosseous nerve palsy	0	-
6.	Inadequate fixation	3	15.0
7.	Radio-ulnar synorlosis	0	-

Tourniquet was applied in two patients only in the beginning of study. Both of them developed tourniquet palsy; so application of tourniquet was abandoned after that in late cases.

TABLE XIII

Time taken for union of fracture in different types of implants.

Time (weeks)	No. of cases		
	Semitubular plates (DCP) with 4.5 mm cortical screws.	Semitubular plates(SFS DCP) with 3.5 mm. cortical screws.	Semitubular plate for ulna & square nail for radius.
9 - 12	1	5	-
13 - 16	4	3	2
17 - 20	1	-	2
21 - 24	-	-	-
Non-union	1	-	1

Average time of union with

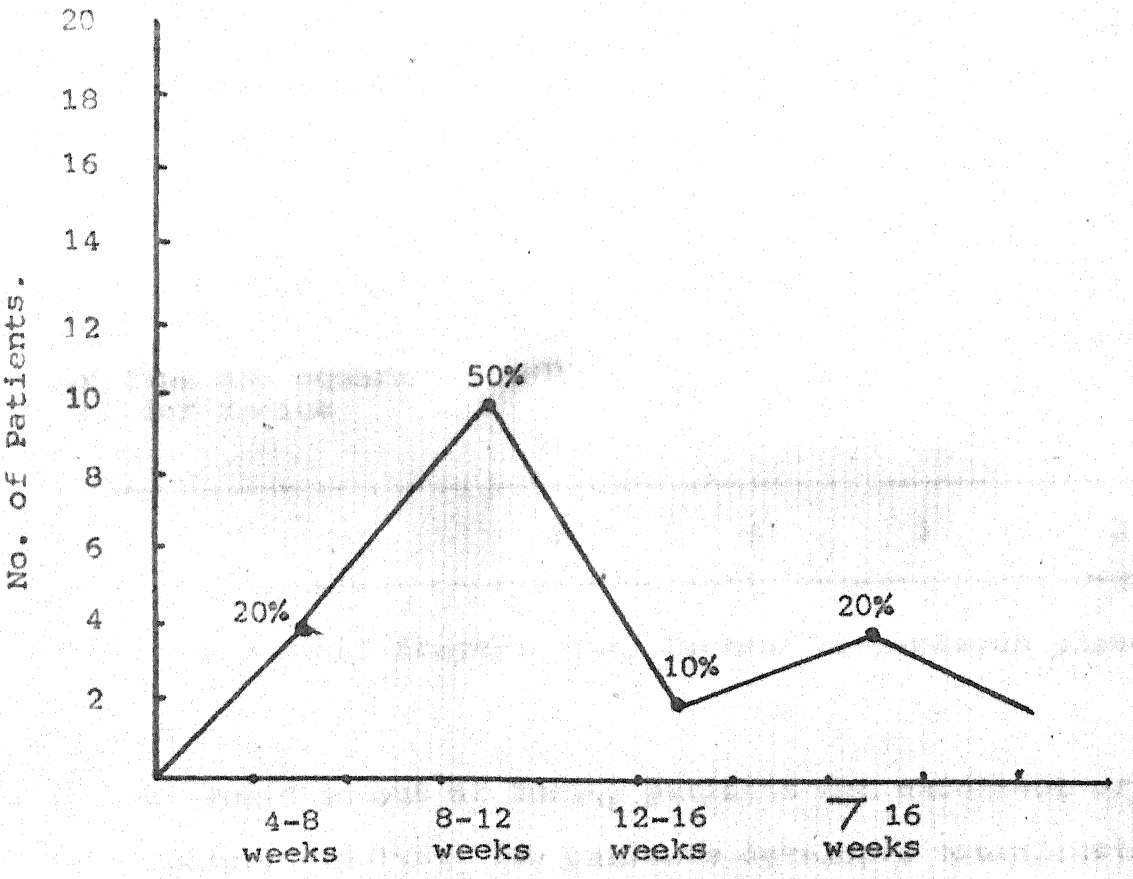
- Semitubular DCP : 14.5 weeks
- Semitubular SFS, DCP : 12 weeks
- Ulnar plating + Radial nailing : 16.5 weeks

* D.C.P. = Dynamic compression plate,

** SFS, DCP = Small fragment set dynamic compression plates.

TABLE XIV

Time interval between injury and return to pre-operative/ gainful employment after open reduction and internal fixation.



Time interval between injury and return to work.

Most of the patients were able to return to pre-operative / gainful employment in less than 12 weeks after injury.

TABLE XV

Functional Results.

Implant used	Excellent	Satis-factory	Unsatis-factory	Failure
Semitubular plate (DCP) with 4.5 mm cortical screws	1	3	1	2
Semitubular plate (*SFS, DCP) with 3.5 mm. cortical screws	5	3	-	-
Semitubular plate for ulna and square nail for radius	0	2	2	1
Total	6	8	3	3

*SFS, DCP = Small fragment set, dynamic compression plate.

Fourteen out of twenty patients had excellent or satisfactory results. Two patients developed tourniquet palsy and one had non-union which was considered as failure of treatment.

****

Pre-operative skiagram A.P. & Lateral view showing fracture of upper 1/3rd.

Immediate post-operative skiagram.

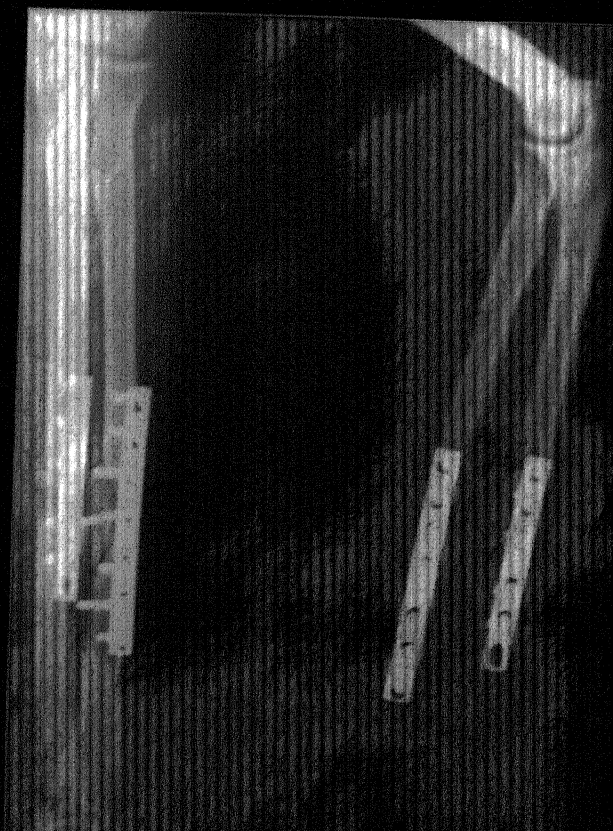
Pre-operative skiagram
A.P. & Lateral view
showing fracture of
middle ⅓rd.

Immediate post-operative
skiagram.

Skiagram after 6 weeks showing bridging callus at fracture site.

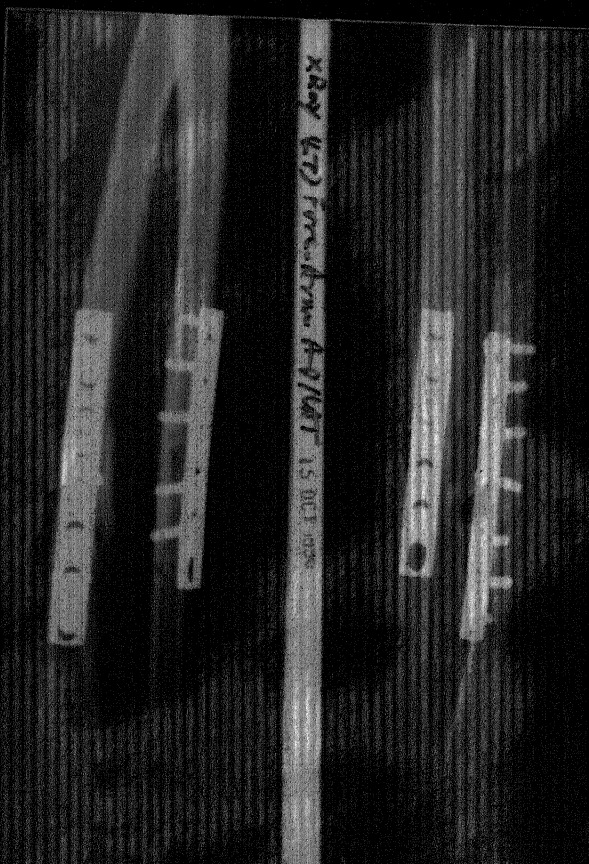
Skiagram after 12 weeks showing union at fracture

Pre-operative skiagram A.P. & Lateral view showing fracture of lower ⅓rd.

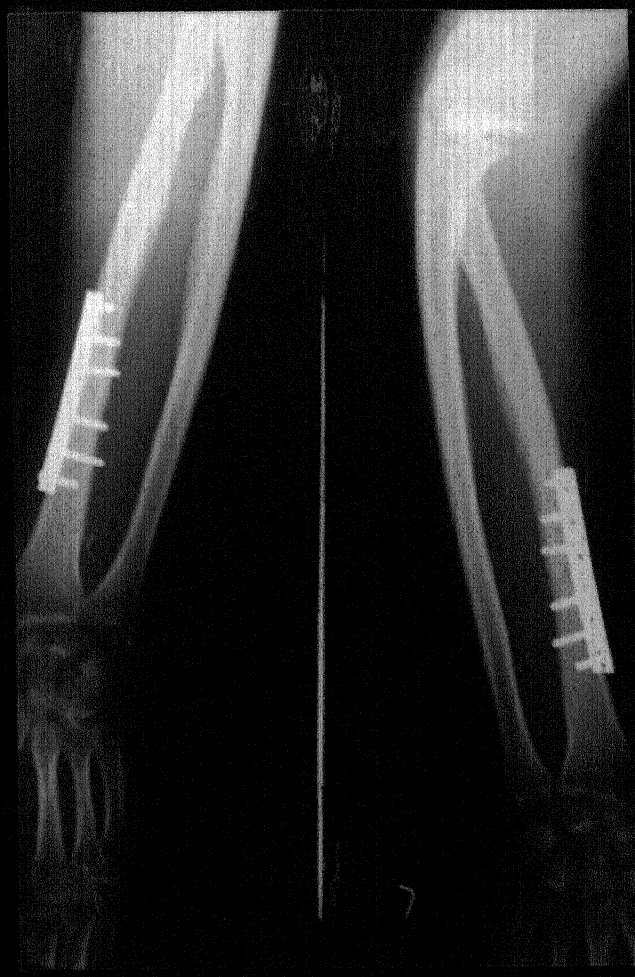


Immediate post-operative skiagram.

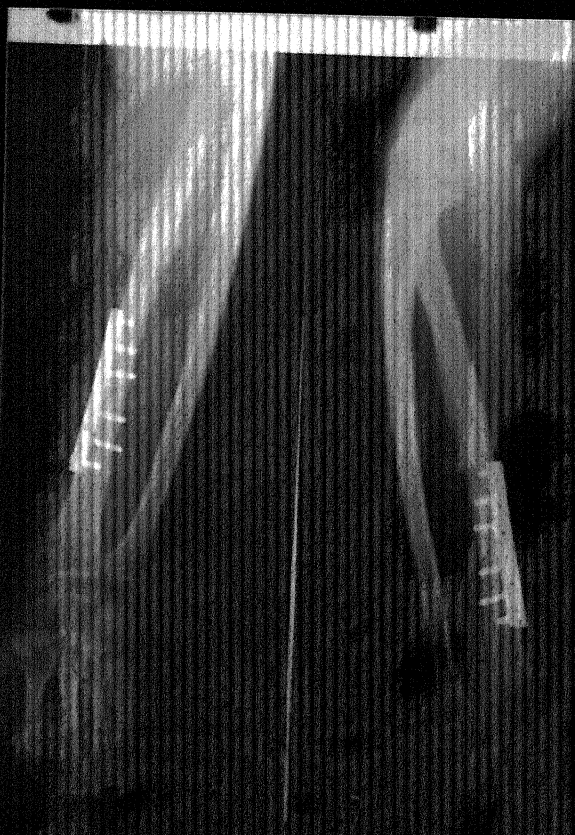
Skiagram after 6 weeks showing bridging callus at fracture site.



Skiagram after 14 weeks showing union at fracture site.



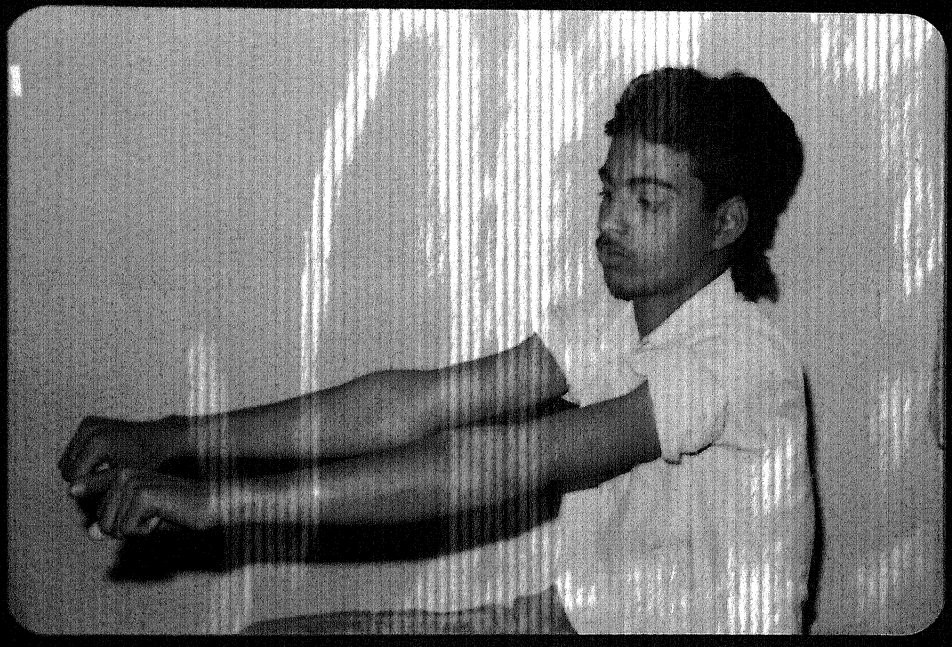
Post-operative skiagram after 4 weeks showing bridging callus at fracture site.



Skiagram after 10 weeks showing union at fracture site.

Case No. 2 after 16 weeks of follow-up.

Showing full flexion at elbow.



Showing full extension of elbow.

Showing full supination.

DISCUSSION

DISCUSSION

The management of choice of displaced diaphyseal fractures of both bones of the forearm in adults has been controversial. Proponents for surgical as well as conservative management have highlighted the merits of their preferred method of treatment and demerits of the other methods. Over the years emphasis has shifted from achieving union to achieving union with good function in the injured limb. Some surgeons like Connolly (1980), Sarmiento & Latto (1981), prefer conservative management. High percentage of unsatisfactory results by conservative methods have been reported by most of the surgeons (Knight & Purvis, 1949; Bolton & Quinlan, 1952; Burwell & Charnley, 1964 and Cruess, 1973).

Pioneering work has been done in improving the metal quality by Venable (1937) and on the concept of compression fixation by Danis (1949), Venable (1951) & Bagby (1958). Danis developed the first compression plate for fixation of fractures of the forearm, and noted that with axial compression and rigid immobilization, a fracture heals with minimum roentgenographic evidence of callus formation, a process that he called healing 'Soudure autogene', or primary bone healing.

There are four areas of osteogenic potential in any healing diaphyseal fracture : the periosteum, the endosteum and medullary cells, the haematoma, and the cortical fracture ends. A common misconception is that the cortical ends undergo resorption back to a point where the cortex is viable.

Schenk & Willenegger showed in both dogs and humans that fractures could unite by primary bone healing if the fragments were rigidly fixed with these blood supply disturbed as little as possible, and that under these conditions resorption and bone formation occurred simultaneously. Perren & associates showed that osteotomized rabbit tibiae rigidly fixed with compression plates could heal by capillaries and haversian systems extending directly across the osteotomy site producing cortex to cortex healing. Anderson & co-workers (1981) observed that with rigid fixation by a compression plate union occurred in medullary canal with no cortilagenous or enchondral phase. They also noticed that microscopic bone formation and bone resorption occurred simultaneously in the cortical ends but without gross resorption visible on the roentgenograms.

Charnley showed that when compression was applied to large cancellous surface (as in arthrodesis of the knee), extremely rapid ossification and union took place. In the case of cortical surfaces, however, he stated that excessive compression may lead to lysis of bone. This view was shared

by Friedenberg & French. However, their conclusion were based on experimental fractures fixed with spring-loaded medullary nails and not with compression plates.

Bassett and Ruedi (1966) in experiments in vitro, showed that mesenchymal cells under compaction in the presence of high oxygen tension might differentiate into osteoblasts, whereas under tension, distraction, or low oxygen concentration they might differentiate into cartilagenous or fibrous tissue cells.

Anderson believe that the major advantages of the ASIF technique are as follows : (i) Compression increases the rigidity of fracture stabilization by impacting the bone ends, (ii) the space between the fragments that must be bridged by new bone is narrowed, & (iii) the developing blood supply is protected by the rigid fixation. They found that in adults the ASIF compression plate is a successful method for obtaining union of acute displaced diaphyseal fractures of the forearm and for restoring the best possible function of the extremity. With the compression early active motion is possible, thus helping to prevent muscle atrophy and joint stiffness.

The better quality of implants together with refinements in instrumentation and technique used for internal fixation have improved the quality of rigid fixation. In addition, the availability of aseptic technique in modern

operation theatres have made surgical procedure safe. In view of these, open reduction and internal fixation has increasingly been the treatment of choice of most of the surgeons.

The present study on closed displaced diaphyseal fractures of both bones of the forearm in adults consist of twenty patients. Most of the patients belong to age group 21 - 30 years (40%) (Table II). The mean age of the patients was 28.25 years. All the patients were male. This was perhaps due to the more vigorous life style of the younger age groups, particularly the males. Burwell & Charnley (1964) have reported, sex of the patient did not affect the time taken for union or the union rate.

Fifty percent cases were urban and fifty percent were rural (Table III) not in accordance with demographic profile of India, according to which ratio should be 30 : 70. This can be due to more dynamic mode of life in urban population so more exposure to injury.

The level of fracture was mostly in upper ⅓rd for radius (41.14%) and middle ⅓rd for ulna (70.50%) (Table VI). Although different surgeons have pointed out different levels of radius and ulna being prone to non-union in the present series, following rigid internal fixation the union rate was not found to be different for different levels of fractures.

Non-dominant limb of the patient was involved in 65 percent of the cases (Table V). Those, with involvement of non-dominant limb were found to return to daily activities much earlier than ones with injury of dominant limb.

Over the years, it has been pointed out by almost all surgeons that achieving satisfactory closed reduction and its maintenance in plaster of paris cast is difficult in displaced fractures of both bones of the forearm (Patrick, 1946; Knight & Purvis, 1949; Comic, 1957; Burwell & Charnley, 1964; Anderson, 1984 & Sisk, 1987). Unsatisfactory results of 74% by Knight & Purvis (1949) and 40% by Bolton & Quinlan (1952) were reported with conservative management of fractures of both bones of forearm in adults. Most of other surgeons have also reported unsatisfactory results with conservative management with few exceptions like Evans (1945). Sarmiento & Latta (1981) and Conolly (1981) have reported good results with early functional bracing. Satisfactory initial reduction, a pre-condition to obtaining good results with functional bracing is not possible in most of the displaced fractures of forearm bones in adults. The technique of functional bracing is also not easy.

Following one unsatisfactory attempt at closed reduction under anaesthesia, patients were treated by open reduction and internal fixation in this study. In most of the patients (85%) open reduction and internal fixation was done within three weeks of injury (Table IX). Surgery was

delayed in 3 patients; out of these three, two were old cases, one was 3½ month old mal-united monteggia fracture dislocation and another was 9 month old non-union of both bones of forearm, third patient had punctured wound over fracture site which took four weeks to heal properly.

Controversies exist regarding the merit of delaying internal fixation following injury. The concept that delayed internal fixation promotes union received support from Smith (1959), Charnley & Guindy (1961), Lam (1964) and Rosacker and Kapta (1981). On the other hand, other surgeons have pointed out that delay in open reduction and internal fixation is less important if fixation is rigid (Hicks, 1961; Olerud & Danckwardt, Lilliastrom, 1969). Lyritis & Co-workers (1983-84) have observed that in fractures fixed rigidly time of operation did not have statistically significant effect on healing process. In the present study, where rigid fixation was used, the union rate of fractures was not found to vary much.

The implants used for fixation included semitubular plates (DCP) for use with 4.5 m.m. cortical screws. Semi-tubular plates (SFS, DCP) for use with 3.5 m.m. cortical screws to fix the fracture. In five patients fracture site for radius was higher up, so square nail for radius and compression plates for ulna with 4.5 m.m. cortical screws were used (Table X). Using ASIF recommended techniques and instrumentation, rigid fixation could be obtained in 14 (70%)

out of twenty forearms (Table X). Heim & Pfeiffer (1982) have stated that fissure fractures may occur when 4.5 m.m. screws are used, especially in slender bones. This problem can be overcome by using SFS, DCP with 3.5 m.m. cortical screws. Hodden & co-workers (1983-84) feel that at the moment the implant of choice for internal fixation of forearm bones is SFS, DCP with 3.5 m.m. cortical screws. In the present study, it was found that technically it was much easier to fix the slender bones with SFS, DCP using 3.5 m.m. cortical screws than with standard DCP using 4.5 m.m. cortical screws. Also, the exposure required was less, thus decreasing the amount of dissection required and operating time.

In the present study, the plates were applied sub-periosteally with minimal stripping of periosteum. Sisk (1987) has recommended the same although Anderson (1984) expressed that plates should be applied extra-periosteally. Since there was no case of delayed union or non-union, in this study except due to implant failure, it is possible that sub-periosteal fixation does not affect the union rate.

Knight & Purvis (1949) had stated that in closing the wound deep fascia should be snugly sutured. This concept has changed since then. Anderson (1984) reported 3 cases of Volkmann's ischaemic contracture in patients in whom deep fascia had been sutured. Closure of deep

fascia is not recommended (Sisk, 1987). In the present study, loose closure of deep fascia was done, keeping in view even if there is superficial infection in any case or few stitches gaps, without closing deep fascia, plate will be exposed particularly in case of ulna which is sub-cutaneous. Proper limb elevation and active finger exercises were encouraged post-operatively. Since none of the operated patients in this series developed any compartment syndrome, it can be said loose closure of deep fascia will not harm if there is proper post-operative elevation of limb is ensured.

In previous studies, there has been no mention of any universally accepted criteria for supplementary bone grafting. In this study, supplementary autogenous cancellous bone chips taken from the patients iliac crest were used for grafting in 3 patients. Two were old case and one patient had significant amount of comminution and operation was also delayed due to time taken for healing of punctured wounds present over fracture site. The bone grafting did not affect the time taken for union of fracture. Anderson and Co-workers (1975) stated that no significant difference was found in rate of union of fractures fixed with or without bone grafting.

There have been varying views regarding post-operative plaster immobilization. Watson Jones (1955), Cave (1958) and Deburen (1967) recommended use of plaster

immobilisation till signs of union of fracture could be seen radiologically. Cowie (1957) and Hicks (1961) on the other hand seldom used post-operative plaster immobilisation. In the present study, post-operative external plaster immobilisation depended upon criteria used by Cruess (1973), Anderson (1984) and Sisk (1987). The factors taken into consideration included patients co-operativeness and intelligence, amount of comminution, adequacy of fixation and whether or not supplementary bone grafting has been done. Based on this, one patient (5%) was not given any external immobilisation following stitch removal. Two patients were given plaster immobilisation upto 4 weeks (10%). Eleven patients were given plaster immobilisation upto 6 weeks (55%). Six patients (30%) were given plaster immobilisation for more than 6 weeks; out of these five patients were those in whom square nailing for radius was done, in effect compromising the adequacy of fixation since beginning.

As pointed out earlier by Sargent & Teipner (1965) and Grace & Eversmann Jr (1980), the patients in the present series also benefitted from comfort and convenience of absence of external plaster immobilisation for longer periods. They could perform every day task which did not involve load bearing or excessive stress on the operated limb. The early return to work in case of patients with sedentary occupation and ability to find alternate employment benefitted all patients in whom external splint was removed early. Four out of twenty patients could return to gainful

employment in less than 8 weeks after injury. Ten out of twenty (50%) did so within 8 - 12 weeks of injury. Two (10%) in whom fixation was not rigid return to work in 12 - 16 weeks of injury, in both of them square nailing was done for radius and compression plating for ulna. Four (20%) patients could return to work only after 16 weeks of injury. Two of these patients developed tourniquet palsy post-operatively and one patient in whom there was extensive comminution and square nailing was done for radius developed non-union of radius and another patient was in whom square nailing was done for radius and compression plating for ulna; later on plate bend and resulted in mal-union (Table XIV).

Different surgeons have given varying time of union of fractures. Knight & Purvis (1949) reported union times of 4.5 to 5 months in both bones forearm fractures treated by open reduction and internal fixation, whereas Anderson and co-workers (1975) reported union times of 7.4 weeks for radius of 7.3 weeks for ulna. In the present study, the time required for union varies with different types of implants used. On an average it was found to be 14.5 weeks with semitubular plates (DCP), 12 weeks with SPS, DCPs and 16.5 weeks with square nail for radius and compression plate for ulna (Table XIII).

Average time required for union was 14.33 weeks. Non-union was seen in two patients (10%) out of twenty

cases (Table XIII). In one patient, with severe comminution of radius, square nailing was done for radius and compression plating for ulna. Due to inadequate fixation patient developed non-union of radius. In other patient with fracture shaft of radius semitubular plating was done with 4.5 m.m. cortical screws. Rigid fixation was seen at the time of operation and patient was mobilised after 4 weeks. Four weeks after mobilisation patient noticed pain in forearm around fracture site, on check radiograph some evidence of metal reaction was found.

The non-union rates reported by other surgeons following open reduction and internal fixation with compression plates vary viz. Sargent & Teipner (1965) 0%, Dodge & Cody (1972) 0% in cases in whom primary internal fixation had been done in their series with 2 out of 28 delayed unions. Naiman & co-workers (1970) also had 0% non-union rates. Anderson and co-workers (1975) reported union rates of 97.9% for radius and 96.3% for ulna. They also stated that most of the failures were due to errors in surgical technique or poor implant quality.

Several post-operative complications were also encountered besides implant failures and non-union (Table XII). Superficial stitch infection occurred in three patients (15%). All the three patients with superficial infection were dressed alternate day with sterile dry bandage and infection subsided in one week.

Deep infection rate was '0' in this series. In all the three patients with superficial infection, union occurred normally and it did not affect the final outcome. Different infection rates reported by different surgeons are Dodge & Cady (1972) - 5.1%, Anderson & co-workers (1975) - 2.9%, Grace & Eversmann Jr. (1980) - 3.1% and Hadden and co-workers (1983-84) - 5.4%. All these studies included patients with compound fractures in whom primary open reduction and internal fixation has been done. Anderson and Co-workers (1975) reported that most of the infections in their series occurred in patients with closed fractures. Perren (1979) in his experimental work showed that bone union can be achieved in the presence of maintained infection with staphylococcus aureus and reported union in 18 out of 19 such cases in sheep tibia.

Neurovascular complications which occurred included tourniquet palsy in two initial patients. One patient was 19 year old boy of both bones forearm fracture; in whom tourniquet was applied for one hour and thirty minutes, another patient was 55 year old male with Galeazzi fracture dislocation; in whom tourniquet was applied simply for one hour. Since the pneumatic tourniquet was not available. It was probably due to inadequate pressure alongwith more time in first patient and atherosclerotic vessels in another patient. All the three nerves i.e. median, ulnar and radial were involved. Both the patients recovered completely after foradic massage, for about 8 weeks.

After these two incidents, use of tourniquet was stopped further and we did not encounter any neuro-vascular complication, nor excessive per-operative bleeding. It was concluded in this study, since plating of forearm bones taken much more time than nailing; so tourniquet should not be applied and neither it is required, considering the complications involved. None of the patient in the present study developed posterior interosseus nerve palsy. The rate of post-operative nerve lesions reported by different surgeons are 10.2% by Dodge & Cody (1972), 2% by Anderson & co-workers (1975), 12.5% by Grace & Eversmann Jr. (1980) and 6.3% by Hadden & co-workers (1983-84). Hadden and co-workers (1983-84) reported significantly less post-operative nerve lesions with the use of SFS, DCP with 3.5 m.m. cortical screws as compared to standard DCP with 4.5 m.m. cortical screws.

Radio-ulnar synostosis did not occurred in any patient in this series. Hadden & co-workers (1983-84) have noted the higher incidence of radio-ulnar synostosis in patients with head injury in whose forearms open reduction and internal fixation has been done. While reporting cross-union rate of 5.4% in their study, they have pointed out that cross-union rate is significantly less with the use of SFS, DCP with 3.5 m.m. cortical screws as compared to standard DCP with 4.5 m.m. screws. Anderson and co-workers reported radio-ulnar synostosis rate of 1.2% in their series.

As there was little periosteal callus due to rigid fixation, there was difficulty in deciding as to when the fracture had united so that the patient could be permitted full load bearing and strenuous activity with the operated forearm. The criteria followed were the disappearance of fracture line and appearance of trabecular continuity as evident on the radiographs. Often, the size of plate made this assessment difficult and radiographs had to be taken in different views besides the routine antero-posterior and lateral views. Commenting on this, Unthoff (1980) had stated the need for the use of scientific criteria to determine the exact moment of fracture healing instead of trusting on emperical criteria.

As is obvious from the above discussion, complications in open reduction and internal fixation may lead to serious functional impairment. Fisher & Hambeen (1978) in a study on compression fixation of long bone fractures have pointed out that the surgeon using these methods should be well versed with them in order to have less complications and should be able to deal with the complications arising out of such treatment.

There are many reports on the results of treatment of displaced diaphyseal fractures of the forearm in adults. Different methods have been employed to treat these fractures. The results reported in different retrospective studies are

difficult to analyse and compare because of uncontrollable variables such as proportions of acute fractures, delayed unions and non-unions, the location and type of fractures, number of open and closed injuries and the extent of associated soft tissue and other injuries. The criteria used to evaluate the results differ so much that comparison are virtually impossible. The functional results are difficult to compare with those in other series in the absence of a standardized rating system for function of the upper extremity.

Two main reasons for performing open reduction and internal fixation in displaced diaphyseal fractures of both bones of forearm in adults are to achieve union and good function. Union and functions were therefore used as criteria to analyse results in the present study, based on the criteria used by Anderson and co-workers (1975) (Table I).

Functional results were excellent or satisfactory in 14 out of 20 (70%) of patients in whom open reduction and internal fixation had been done (Table XV). Three patients with inadequate fixation took long period to mobilize had unsatisfactory results. Two patients who developed tourniquet palsy and one in whom implant failure led to non-union of radius were considered as failure of treatment.

Functional results in different series have been reported using criteria which vary considerably. Acceptable results reported have been 66% by Burwell & Charnley (1964); 78% by Dodge & Cody (1972); 82% by Anderson & co-workers (1975); 80% by Grace & Eversmann Jr. (1980) and 80% by Hadden & co-workers (1983-84).

The role of supervised physiotherapy is of immense help to the patient in early recovery of good range of motion in joints of the operated limb and good muscle strength.

Extensive experimental works of Perren and co-workers (1969), Paavolainen and co-workers (1978) and Allgower and Spiegel (1979) on the concept of rigid internal fixation of fractures with early mobilisation of injured extremity have helped in shifting the trend towards open reduction and rigid internal fixation of fractures. Better techniques of anaesthesia, strictly aseptic operating environments and instruments, better implant quality and instrumentation for internal fixation and atraumatic techniques of surgery have led to low rates of complications and better functional results in fractures treated by open reductions and rigid internal fixation.

Although the present study has too small number of patients compared to the earlier mentioned studies, to make statistical comparisons, it has clearly shown that most

cases of displaced diaphyseal fractures of both bones of the forearm in adults have to be taken up for early open reduction and internal fixation.

Excellent functional results associated with a high union rate, were possible, in the present study due to availability of recommended manual and adequate instrumentation, strict adherence to the modern techniques of compression osteosynthesis and gentle tissue handling under aseptic operating conditions.

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C O N C L U S I O N S

CONCLUSIONS

After evaluating the results in the present series, it is evident that semitubular (DCP) plates provides rigid internal fixation and give excellent functional results due to early mobilisation.

Although the total number of patients treated were inadequate for statistically significant conclusion, the results are in agreement with several other studies (Naiman & co-workers, 1975; Grace & Eversmann Jr. 1980; Hadden & co-workers, 1983-84) which clearly proven the advantages of early open reduction and internal fixation over that of conservative treatment.

The following conclusions were drawn -

1. It is difficult to achieve satisfactory reduction in closed, displaced, diaphyseal fractures of the forearm in adults.

2. The implants used included semitubular plates (DCP) with 4.5 m.m. cortical screws, SFS DCPs with 3.5 m.m. cortical screws. Square nailing for radius in higher up fractures along with compression plating of ulna.

3. Semitubular plates provided the rigid internal fixation.

4. Square nailing of radius with compression plating of ulna provides inadequate fixation and should not be used as it abolishes the advantages of compression plating.

5. Average time taken for union was 14.33 weeks.

6. Tourniquet was applied in two patients, both of them developed tourniquet palsy. Later on application of tourniquet was stopped.

We concluded tourniquet should not be applied for forearm plating as bleeding is not too-much.

7. Early open reduction and internal fixation was found to provide excellent functional results in most of the cases.

8. Patients in whom early open reduction and internal fixation was done were able to return to gainful employment earlier.

9. Early removal of external immobilisation following rigid internal fixation, was possible in most of the patients.

10. Correct rotational alignment and pronation, supination movement were regained in most of the patients.

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BIBLIOGRAPHY

BIBLIOGRAPHY

1. Allgower, M., Ehrsam, R., Ganz, R., Malter, P. and Perren, S.M. : Clinical experience with a new compression plate 'DCP'. Acta Orthopaedica Scandinavica. Supplement No. 125 : 45, 1969.

2. Allgower, M. and Spiegel, P.G. : Internal fixation of fractures. Clinical Orthopaedics and Related Research. 138 : 26, 1973.

3. Anderson, L. : Compression plate fixation and effect of different types of internal fixation on fracture healing. J. Bone Joint Surg., 47-A : 191, 1965.

4. Anderson, L.D. : Author, Chapter on fractures of shafts of the Radius and Ulna. In: "Fractures in Adults", Vol. I, 2nd edition, edited by Rockwood Jr. and Green, D.P., J.B. Lippincott Company, 1984.

5. Anderson, L.D., Sisk, T.D., Park, W. and Tooms, R.E. : Compression plate fixation in acute diaphyseal fractures of the radius and ulna. J. Bone Joint Surg., 57-A : 287, 1975.

6. Bagby, G.W. and Janes, J.M. : The effect of compression on the rate of fracture healing using a special plate. Amer. J. Surg., 95 : 761, 1958.

7. Basset, C.A.L.D., Ruedi, T.P. : Transformation of fibrous tissue to bone in viva. Maline, 209 : 988-989, 1966.

8. Benjamin, A. : Author, Chapter on Injuries of the Forearm in Watson-Jones, Fractures and Joint Injuries, Vol. 2, 6th edition, edited by J.N. Wilson, Churchill Livingstone, 1982.

9. Bohler, L. : The treatment of Fractures, Vol. 1, 5th edition. Grune and Stratton, New York and London, 1956.

10. Bolton, H. and Quinlan, A.G. : The conservative treatment of fractures of the shaft of the radius and ulna in adults. The Lancet, ii : 700, 1952.

11. Boyd, H.B., Lipinski, S.W. and Wiley, J.H. : Observations on non-union of the shafts of the long bones with a statistical analysis of 842 patients. J. Bone Joint Surg., 43-A : 159, 1961.

12. Bradford, C.H., Adams, R.W. and Kilfoyle, R.M. : Fractures of both bones of the forearm in adults. Surg. Gynae. Obstet., 96 : 240, 1953.

13. Burwell, H.N. and Charnley, A.D. : Treatment of forearm fractures in adults with particular reference to plate fixation. J. Bone Joint Surg., 46-B : 404, 1964.

14. Caden, J.G. and Jackson, M.D. : Internal fixation of fractures of the forearm. J. Bone Joint Surg., 43-A : 1115, 1961.

15. Cave, E.F. : Fractures and other injuries. The Year Book Publishers Inc. Chicago, 1958.

16. Charnley, J. : The closed treatment of common fractures. 3rd edition. Churchill Livingstone, Edinburgh & London, 1961.

17. Charnley, J. and Guindy, A. : Delayed operation in the open reduction of fractures of long bones. J. Bone Joint Surg., 43-B : 664, 1961.

18. Charnley, J.C. : Positive pressure in Arthodesis of the knee joint. J. Bone & Joint Surg., 30-B : 478-486, Aug., 1948.

19. Connolly, J.F. Editor, : DePalma's the management of fractures and dislocations, an Atlas. Vol. 1, 3rd edition, W.B. Saunders Company, London, Philadelphia, Toronto, 1980.

20. Cowie, R.S. : Fractures of the forearm treated by open reduction and plating. The Brit. J. Surg., 44 : 263, 1957.

21. Cruess, R.L. : The management of forearm injuries. Orthopaedic Clinics of North America, 41(4) : 69, 1973.

22. Danis, R. : The Classic, The Aims of Internal Fixation. Clinical Orthopaedics and Related Research, 138 : 23, 1979.

23. Danis, Robert : Thearie et pratique del'osteosynthese PP. 95-105, Paris, Mosson et Cie, 1949.

24. DeBuren, N. : Causes and treatment of non-union in fractures of the Radius and Ulna. J. Bone Joint Surg., 44-B : 614, 1962.

25. Denham, R.A. : Proceedings and reports of universities, colleges, councils and associations. British Orthopaedic Association, 50th Anniversary Meeting. J. Bone Joint Surg., 51-B : 177, 1969.

26. DePalma, A.F. : The management of fractures and dislocations, an atlas. Vol. I, 2nd edition, W.B. Saunders Company, Philadelphia, London, Toronto, 1970.

27. Dodge, H.S. and Cady, G.W. : Treatment of fractures of the radius and ulna with compression plates. J. Bone Joint Surg., 54-A : 1167, 1972.

28. Evans, Major, E.M. : Rotational deformity in the treatment of fractures of both bones of the forearm. J. Bone Joint Surg., 27 : 373, 1945.

29. Fisher, W.D. and Hamblen, D.L. : Problems and pitfalls of compression fixation of long bone fractures : A review of results and complications. Injury, 10 : 99, 1978.

30. Grace, T.G. and Eversmann Jr., Colonel, W.W. : Forearm Fractures. J. Bone Joint Surg., 62-A : 433, 1980.

31. Hadden, W.A., Reschauer, R., Seggl, W. : Results of AO plate fixation of forearm shaft fractures in adults. Injury, 15 : 44, 1983-84.

32. Heim, U. and Pfeiffer, K.M. : Small fragment set manual. Springer-Verlag. Berlin. Heidelberg, New York, 1982.

33. Heppenstall, R.B. : Editor, Fracture treatment and healing. W.B. Saunders Company, 1980. Philadelphia, London, Toronto, 1980.

34. Hicks, J.H. : Fractures of the forearm treated by rigid fixation. J. Bone Joint Surg., 43-B : 680, 1961.

35. Hidaka, S. and Gustilo, R.B. : Refractures of bones of the forearm after plate removal. J. Bone Joint Surg., 66-A : 1241, 1984.

36. Holdsworth, F.W. : In: Modern Trends in Orthopaedics Fracture Treatment, edited by JPM Clark, London, Buttersworth, 1962.

37. Hughston, J.C. : Fractures of the distal radial shaft : Mistakes in management. J. Bone Joint Surg., 39-A : 249, 1957.

38. Jinkins, W.J., Lockhart, L.D. and Eggers, G.W.N. : Fractures of the forearm in adults. South. Med. J.,

39. Key, J.A. : Positive pressure in arthadesis of tuberculosis of the knee joint. Southern Med. J., 25 : 909-914, 1932.

40. Key, J.A. and Conwell, H.E. Editors. The Management of Fractures, Dislocations and Sprains. 5th edition. The C.V. Mosby Company, 1951.

41. Knight, R.A. and Purvis, G.D. : Fractures of both bones of the forearm in adults. J. Bone Joint Surg., 31-A : 755, 1949.

42. Lam, S.J. : The place of delayed internal fixation in the treatment of fractures of the long bone. J. Bone Joint Surg., 46-B : 393, 1964.

43. Lettin, A.W.F. : Proceedings and reports of Universities, Colleges, Councils & Associations. British Orthopaedic Association, 50th Anniversary Meeting. J. Bone Joint Surg., 51-B : 177, 1969.

44. Lyritis, G., Th.Loannidis and Hartofylakidis-Garofallidis G. : The influence of timing and rigidity of internal fixation on bony union of fractures of the forearm. Injury, 15 : 53, 1983-84.

45. Marek, F.M. : Axial fixation of forearm fractures. J. Bone Joint Surg., 43-A : 1099, 1961.

46. Muller, M.E., Allgower, M., Schneider, R., Willenegger, H. : Manual of Internal Fixation, 2nd edition. Springer-Verlag. Berlin, Heidelberg, New York, 1979.

47. Naiman, P.T., Schein, A.J. and Siffert, R.S. : Use of ASIF compression plates in selected shaft fractures of the upper extremity. A preliminary report. Clin. Orthop. & Related Res., 71 : 208, 1970.

48. Olerud, S. and Dackenwardt-Lilliestrom. : Fracture healing in compression osteosynthesis in the dog. J. Bone Joint Surg., 50-B : 844, 1969.

49. Paavolainen, P., Karaharju, E., Slatis, P., Ahonen, J. and Holmstorm, T. : Effects of rigid plate fixation on structure and mineral content of cortical bone. Clinical Orthopaedics and Related Research, 136 : 287, 1978.

50. Patrick, J. : A study of supination and pronation with especial reference to the treatment of forearm fractures. J. Bone Joint Surg., 28 : 737, 1946.

51. Perkins, G. : Fractures and dislocations. University of London. The Athlone Press, 1958.

52. Perren, S.M. : Physical and biological aspects of bone healing with special reference to internal fixation. Clinical Orthopaedics and Related Research. 138 : 175, 1979.

53. Perren, S.M., Huggler, A., Mathys, R., Russenberger, M., Allgower, M., Schenk, R., Willenegger, H. and Muller,M.E.: The reaction of cortical bone to compression. Acta Orthopaedica Scandinavica Supplement No. 125 : 19, 1969.

54. Perren, S.M., Russenberger, M., Steinmann, S., Muller,M.E., Allgower, M. : A dynamic compression plate. Acta Orthopaedica Scandinavica. Supplement No. 125 : 31, 1969.

55. Ralston, E.L. : Handbook of Fractures. The C.V. Mosby Company, Saint Louis, 1967.

56. Rosacker, J.A. and Kopta, J.A. : Quoted by Anderson, L.D. (1984) : In: Chapter on Fractures of the Shafts of the Radius and Ulna in Fractures in Adults, Vol. I, 2nd edition, edited by Rockwood Jr. and Green, D.P.

57. Rosacker, J.A. and Kopta, J.A. : Both bone fractures of the forearm : a review of surgical variables associated with union. Orthopaedics, 4 : 1353, 1981.

58. Sage, F.P. : Medullary fixation of fractures of the forearm : a study of the medullary canal of the radius and a report of fifty fractures of the radius treated with pre-bent triangular nail. J. Bone Joint Surg., 41-A : 1489, 1959.

59. Sargent, J.P. and Teipner, W.A. : Treatment of forearm shaft fractures by double plating. J. Bone Joint Surg., 47-A : 1475, 1965.

60. Sarmiento, A., Cooper, J.S. and Sinclair, W.F. : Forearm fractures - Early functional bracing - a preliminary report. J. Bone Joint Surg., 57-A : 297, 1975.

61. Sarmiento, A. and Latta, L.L. : Closed functional treatment of fractures. Springer Verlag, Berlin, Heidelberg, New York, 1981.

62. Schenk, R. and Willenegger, H. : Morphological findings in primary fracture healing. Symp. Biol. Hungarice., 7 : 75-86, 1967.

63. Sisk, T.D. Author, : Chapter on General Principles of Fracture Treatment. In: Campbell's Operative Orthopaedics, Vol. 3, 7th edition. The C.V. Mosby Company, St. Louis, Washington, D.C, Toronto, 1987.

64. Smith, H. and Sage, F.P. : Medullary fixation of forearm fractures. J. Bone Joint Surg., 39-A : 91, 1957.

65. Smith, J.E.M. : Internal fixation in the treatment of fractures of the shafts of the Radius and Ulna in Adults. J. Bone Joint Surg., 41-B : 122, 1959.

66. Stuck, W.G. and Thompson, M.S. : Treatment of fractures of the forearm with intramedullary pins. Amer. J. Surg., 77 : 12, 1949.

67. Teipner, W.A. and Mast, J.W. : Internal fixation of forearm diaphyseal fractures: Double plating versus single compression (Tension Band) plating - A comparative

68. Unthoff, H.K. : Current concepts of Internal Fixation of Fractures. Springer-Verlag, Berlin, Heidelberg, New York, 1980.

69. Undeland, K. : Rotational movements and bony union in shaft fractures of the forearm. J. Bone Joint Surg., 44-B : 340, 1962.

70. Venable, C.S., Stuck, W.G. and Beach, A. : The effects on bone of the presence of metals : Based upon electrolysis - An Experimental Study. Annals of Surgery, 105 : 917, 1937.

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